This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

ON
MARINE ENGINE
CONSTRUCTION & CLASSIFICATION

BY

CHARLES ATHERTON.

Mechanics

ON

MARINE ENGINE CONSTRUCTION AND CLASSIFICATION.

ON

MARINE ENGINE CONSTRUCTION

AND

CLASSIFICATION.

BY

CHARLES ATHERTON,

MEM. INST. C. E.,

CHIEF ENGINEER H. M. DOCKYARD, DEVONPORT,

FORMERLY OF QUEEN'S COLLEGE, CAMBRIDGE, AND LATE MANAGING ENGINEER IN THE
FIRM OF CLAUD, GIRDWOOD, AND CO., MARINE ENGINE
MANUFACTURERS, GLASGOW.

Dedicated, by Permission,

TO THE RIGHT HONOURABLE

SIR JAMES ROBERT GEORGE GRAHAM, BART., M.P.,

&c. &c. &c.

LONDON:
JOHN WEALE, 59, HIGH HOLBORN.
1851.

BIBLIOTHECA·BODLEIANA·

LONDON:
J. S. HODSON, PRINTER, 22, PORTUGAL STREET,
LINCOLN'S INN.

To

THE RIGHT HONOURABLE

SIR JAMES ROBERT GEORGE GRAHAM,

BARONET, M.P.,

&c. &c. &c.

SIR,

The gratifying privilege which attaches to publication, is, that it affords the author an opportunity, sanctioned by custom, of acknowledging his obligations to those whose favourable notice may have conduced to the production of his work. Actuated by these feelings, I would express my gratitude to the Most Noble the Marquis of LANSDOWNE, whose patronage has on various occasions forwarded my prospects; to the Right Honourable the Earl of ELLENBOROUGH to whom, as First Lord of the Admiralty, I am indebted for my introduction to the public service; to the memory of the Right Honourable the late Earl of AUCKLAND, whose favourable notice promoted me to my present position; to Sir HENRY G. WARD, late

Secretary to the Admiralty, whose liberality of sentiment encouraged and supported me in the free expression of my professional opinions; and to the Right Honourable Sir FRANCIS T. BARING, First Lord of the Admiralty, whose expressed approval of my bringing before the public a practical illustration of the views which I entertain on marine engine construction, has placed me personally on vantage ground, which, as a public servant, I might not otherwise have ventured to assume, even in the path of scientific pursuit.

These are the personages to whom my acknowledgments are due on private considerations,—nevertheless, it is to you, Sir, that, with permission, I dedicate my humble effort, in the hope of further promoting a CAUSE which I conceive to be of public importance. Still, however, being personally a stranger to yourself, you may be doubtful as to the motives which induced me to solicit this honour of one in your distinguished position;—permit me, therefore, to say that I am actuated by no private feeling in respect of the past or of the future, but, devoted as you have been for many years, to the maritime interests of the country, I would desire to attract your notice, in the expectation that your sentiments may be consonant with my labour.

I regard you, Sir, as holding opinions, differing in some respects from the views which I humbly entertain, as to the system of procedure best adapted to meet the constructive requirements of the Royal Navy; nevertheless, Sir, I would do homage to the acumen which your intelligence brings to bear on all enquiries touching the administration of steam ship service,—to the unbiassed thought with which you weigh all evidence on practical matters, foreign to your own immediate experience,—to the judgment with which, embracing all points of consideration, you would decide on the broad question of the public good,—and to the decision of character, purpose and action, with which you would uphold, and prosecute such measures as you may conceive to be conducive to the maritime prosperity of Great Britain.

I have the honour to be,

SIR,

Your most obedient and humble servant,

CHARLES ATHERTON.

Devonport,
April 10, 1851.

PREFACE.

INTRODUCTORY to the following treatise on marine engine construction and classification, the writer desires to facilitate its perusal by announcing the object which he has in view, and the course of enquiry intended to be pursued. By this preparatory explanation, it is hoped that the reader will be familiarized with the subject before him, and that persons not conversant with scientific enquiries may be induced to give it their attention, by being apprised that, although the matters to be discussed are of a mechanical and scientific character, it is the purpose of the writer to divest them of technicalities, and to convey a popular apprehension of the present position of maritime engineering, by referring to the recorded results of experience, and by addressing himself to the general intelligence which conducts and regulates ordinary business affairs: by thus dispelling the exclusive character which usually attaches to scientific enquiry, the author hopes to render the engine department of the steam ship subject to the controlling influence of mercantile intelligence, whence he anticipates that the powerful agency of steam will be put in train for being more effectually wielded in the advancement of commercial interests, and in the cause of national progress.

To the end above stated, the *primary* object which the writer has in view is to establish the PRINCIPLE of engine classification; that is, that the engines employed in steam shipping establishments constituting independent FLEETS, (such, for example, as the respective fleets of merchant steamers already established, and which may hereafter be originated,) be constructed (all the engines for each fleet respectively) on the same general plan of arrangement, and that the variations of power be regulated by a definite *scale of sizes*, constituting a CLASSIFICATION SYSTEM. The full development of these views would render it desirable that all the different commercial companies should adopt one system only, identical with that which may be adopted in their national service; but this unanimity, however desirable, is by no means indispenable to the *principle* of the proposed measure, which consists in this, that each independent company adopt *some system*, and introduce it gradually, as the opportunities of renewal and extension of their engine stock will practically admit.

The particular system of construction and classification now publicly brought forward by the Author, has been adduced to exemplify one method of giving practical effect to the principle which he advocates; the constructive details of this plan are based on the investigations announced by the following treatise, and on the conclusions deduced therefrom. The suggested system is not advanced to the exclusion of other proposals, but rather as exemplary, to incite similar investigations and research, and the Author has given practical effect to his proposals, by constructing a pair of engines of 25 horse power for exhibition, as being the most complete and satisfactory mode of illustrating his views.

It may now be premised that the following treatise on marine engine construction and classification consists of twelve chapters or SECTIONS, each of them treating separately on points of consideration immediately bearing on the subject under discussion, and which may be briefly explained as follows:—

SECTION I., page 1 to 5, refers to the growing importance of maritime engineering, and to its probable future influence as the agency by which great national interests will be prosecuted; which agency, to be in the highest degree efficient, must be subjected to the control of regulation discipline, to effect which, a definite arrangement of marine engine construction and classification becomes indispensable.

SECTION II., page 6 to 19, refers to the general practice which has hitherto regulated steam shipping management in the matter of engine construction;—points out the deficiencies of the practice referred to as in great measure superseding all professional *responsibility* for the efficiency of steam ship construction; and shews that it affords no guarantee for *progressive improvement* in steam ship locomotive performance with reference to the power employed, based on the results of *previous experience.*

SECTION III., page 20 to 27, refers to the Exhibition of 1851, as a favourable opportunity for drawing public attention to the subject of engine classification : it also brings under consideration the various principles of marine engine construction on which practical efficiency appears to be chiefly dependant, and refers to a purposed course of comparison which will effectually test whether classification can be introduced without sacrifice of engine efficiency, and with the probability of realizing an improved average performance.

SECTION IV., page 28 to 33, refers to the causes which have induced the great *diversity* of different plans of MARINE ENGINE construction now in operation; shews that none of these varieties have been acknowledged to supersede the constructive *principles* of the sway beam engine as regards working efficiency; and states the grounds on which the principle of the sway beam engine is to be preferred as the base of a classification system.

SECTION V., page 34 to 42, refers to the variety of BOILERS that have been introduced, points out the distinctive operation of flue and tubular boilers, and proposes the adoption of the TUBULAR BOILER with furnaces combined agreeably to the usual practice of constructing the furnaces of *flue* boilers, as being a principle of boiler construction well adapted for classification.

SECTION VI., page 43 to 46, refers to the different modes of propelling vessels, viz., by the agency of the PADDLE WHEEL, and by the submerged SCREW PROPELLER; refers to the screw propeller as being equally effective with the paddle wheel for general purposes, and more so for certain special purposes: hence, the probability of the screw propeller superseding the paddle wheel, and the consequent necessity for the classified construction of engines being especially adapted for the submerged screw propeller, though applicable also to the paddle wheel.

SECTION VII., page 47 to 51, refers to the difference of locomotive effect, with reference to the power employed, apparently attributable to screw ship engines being connected DIRECTLY with the screw shaft, or connected by the agency of MULTIPLYING GEAR; adduces experimental trials of screw ships, as indicating the superior efficacy of connecting by the agency of *multiplying gear;* and, consequently, infers that the classified construction of engines ought to be adapted to carrying out this mode of connecting the engine with the screw shaft.

SECTION VIII., page 52 to 60, refers to the *length* of engine STROKE; deduces, by investigation of the results of screw ship experience, the remarkable conclusion that, for engines up to sixty inches diameter of cylinder, a two feet stroke is preferable to a longer stroke for the purpose of screw propulsion; and, consequently, infers that the classified construction of engines may be limited to two feet length of stroke.

SECTION IX., page 61 to 67, refers to the necessity for the machinery of ships of war being placed as low as possible in the hold of the vessel, and that as marine boilers have been satisfactorily constructed of the limited height of eight feet, the height of the engines ought not to exceed that limit; shews, by reference to Diagrams drawn to scale, that the stroke being limited to two feet, the plan of engine construction proposed by the Author, on the *sway beam* principle, with vertical cylinders of *two feet stroke* up to sixty inches diameter, and adapted for the application of *multiplying gear*, is practicable within the limited height of *eight feet;* and, consequently, that the proposed construction embraces those requirements which have been shewn to be highly conducive to the effective performance of screw ship engines.

SECTION X., page 68 to 75, refers to the received rule for calculating the "*nominal horse power*" as not applicable for determining the capabilities of marine steam engines; shews that statements of engine performance and consumption of fuel based on the "nominal horse power," does not afford a satisfactory criterion of engine "duty," or afford the desired means of testing the merits of the management afloat, and that an improved system of classified construction is necessary for attaining that object. The gross moving force exerted by the piston of a steam engine, is capable of being determined by the aid of an instrument called the indicator, and is denominated the "INDICATED HORSE POWER," which measure of power is referred to and adopted in Section XI.

SECTION XI., page 76 to 82, refers to the *variations* of "indicated horse power" which an engine of *given size* will produce, according as it is worked with steam at a greater or less pressure, and under various other circumstances under the control of the engineer; shews that if a series of sizes be adopted,—say of 10, 20, 30, 40, 50, 60, 70, and 80-inches diameter of cylinders and two feet stroke, the available *maximum power* of any one engine will exceed the available *minimum power* of the next greater size, and consequently that a *series* of engines of determined sizes, will, one or other of them, produce any amount of power whatever between the minimum of the smallest size and the maximum of the largest, and consequently, that one or other of the eight sizes, above referred to, will produce any amount of power whatever that may be required, between the extreme limits of the powers now in use, just as well, for all practical purposes, as by the present unregulated practice:—or, in other words, one or other of the above system of classified engines would be fit to take the place of any one of the one thousand engines and upwards of ***dissimilar sizes and constructions*** which are now actually employed in the commercial and national service of Great Britain.

SECTION XII., page 83 to 87, refers specifically to the ***economic*** advantages to merchant steamers, and to the ***greater efficiency*** of ships of war, which a classified system of marine engine construction is capable of effecting.

Having thus fully explained the purport of the following treatise, the Author submits the ***principle*** of his proposition to the test of public opinion, observing that the plans now published, and the engines exhibited to elucidate his views, are merely an approximation to the more carefully matured details, by which the PRINCIPLE, when approved and sanctioned, may be put into practical execution, it being purposed that the detail drawings of the classification construction be made the subject of future publication, should the work now submitted be favourably entertained.

CHARLES ATHERTON.

NOTE.—The Appendix refers to a construction of Expansion Gear originally invented and patented by the Author, in 1833, and further improved in 1850,—and which is now particularly referred to, it being considered that the complete carrying out of the principle of Expansion, and duly recording, by self-acting registration, the varying extent to which it is employed on board ship, constitutes the most practicable means by which the management afloat can be duly checked, and economic efficiency in conducting the service be most effectually realised.

SECTION I.

STEAM HAVING BECOME AN IMPORTANT ELEMENT OF NATIONAL POWER, REQUIRES THAT ITS APPLICATION IN CONNECTION WITH STEAM FLEETS, BE EFFECTIVELY SYSTEMATISED.

THE following Exposition on Marine Engine Construction, has been drawn up with the object of attracting attention to the importance and practicability of more completely systematising the mechanical arrangements, whereby steam is made available in navigation as an element of motive power.

This view of the requirements of steam shipping service has been induced by the consideration, that "*system,*" in the application of mechanical power, and "order" in conducting its effects, is analogous to "*discipline*" in the regulation of military armaments; and that, in proportion as the system which constitutes discipline in mechanical agency may be improved, so will the means employed be rendered more effective to the realisation of the object in view.

As respects the national importance of the subject thus brought under consideration, it has already become apparent that steam navigation has attained a degree of importance, as an element of naval power, which threatens to be prominently instrumental in controlling the events of war; and the relative scale of operation in which the *commercial* enterprise of different countries may hereafter be prosecuted by the agency of steam, equally promises to be the base of preponderating influence in times of peace.

Doubtless other sources of elementary power, as, for instance, the galvanic agency, and various chemical developments other than that of steam, may still be in abeyance, and may hereafter signalise successive epochs in the intellectual progress of mankind; as refined scientific investigation conspicuously distinguished certain ages that have passed, and as "utilitarianism," or the practical application of those discoveries, has already prominently ranked itself among the historical events of the present century.

But speculations on the future, however interesting in their nature, must not be permitted to check the ardour with which we would pursue the practical application of the realized knowledge which has been transmitted to the age we live in, or achieved by ourselves, and by which, in many instances, the powers of nature herself are rendered subservient to human direction, and made the base of future progress.

The practical application of steam to marine purposes, is that department of science which we now purpose to investigate. It will be admitted that the elements of steam motive power, viz., combustion, heat, vapour, and vacuum, constitute, at the present time, the most available known means of producing an illimitable, but, at the same time, a controllable effective force, the influence of which on the interests of the commercial world, and even on the naval power of nations, being acknowledged to be all important; it is hoped that the following remarks, written with the primary object of demonstrating the *practicability* of SYSTEMATISING the application of steam, will be publicly useful,—directly through the views and investigations now announced, and indirectly through being the means of eliciting the further research and information which public discussion is sure to excite. The subject of practical enquiry now submitted for consideration, constitutes a proposal for bringing under a state of more effective discipline, the respective steam ship establishments of the country employing several vessels under one direction, as is the case with numerous commercial companies, owning FLEETS of from ten to twenty and even up to fifty ships, and especially so with the royal navy, amounting to one hundred and fifty steamers, which are propelled by a collective force, denoted by 50,000 horses' power:—a subject, therefore, of vital import, which may be expected to attract not merely the curiosity of scientific enquiriers, but also to engage the attention of mercantile intelligence, responsible for the administration of commercial affairs which directly affect the pecuniary interests of thousands, and of statesmen, responsible for the destiny of nations. All parties, in whatever way interested in the important subject of steam fleet efficiency, are invoked to aid the cause of national advancement, dependant, as in great measure it now is, on the effective application of steam, by recognising, confirming, and adopting such views as shall be found correct in principle and sound in practice. Britain, from her maritime position, and from the magnitude of her commercial relations, is interested above all nations in the issue of such an enquiry.

The enquiry thus brought forward for consideration, and the views advanced thereon, are not the result of recently formed and tacitly entertained opinions, but the course of observation from which the propositions hereinafter advanced have been propounded, the experience on which they are based, and the constructive details by which the mechanical efficiency of the proposed plan is intended to be tested, are in great measure the result of practice on the part of the writer as a manufacturer of marine steam engines, and engineer engaged in the professional superintendance of steam power on the largest scale.

But progress in the adaptation of science to practical use, peculiarly demands the aid of professional exposition. In the prosecution of great undertakings, a combination of qualifications is required which no individual intelligence can embrace, and the directing parties in charge of such affairs cannot incur the responsibility of adopting any new course of procedure, whether philosophical or mechanical, not directly in the sphere of their own experience, unless supported in that course by the conclusive reasoning of those whom they may consult. In steam ship affairs, particularly, projected as they now are for the most part on a scale of pecuniary investment which can only be met by the united influence of joint stock companies, or upheld by national resources, the responsibility of those who may be intrusted with direct control, becomes increased, proportionally with the magnitude of the charge, and caution in their administration becomes essential; but it must be exercised with the discrimination that checks reckless *innovation* without obstructing rational PROGRESS.

Amongst the individuals usually deputed to the direction of steam affairs, only few, comparatively, are competent to entertain the scientific and mechanical details which are involved in the practical department of marine engine construction; the rivalry of marine engine manufacturers is regarded as the best guarantee for engine efficiency, and from them it is expected that all improvements in mechanical arrangement should emanate: generally, however, parties employed under contract in the distinct department of *manufacturing* operations, are not directly interested in the commercial benefit which would result from any improved system of *organization* and management, producing the effect of reduced investment, and reduced current expenditure, in connection with the original establishment and subsequent upholding of steam FLEETS. Many, indeed, are the difficulties which attend the introduction of practical reformation, when dependant on the mutual co-operation of numerous individuals entertaining different views, affected by different apprehensions, and incurring different degrees of responsibility by the adoption of a proposed change;—but the adaptation of steam to maritime affairs has now assumed an influence which requires being controlled by decisive action, and in the direction of which it will be usefully borne in mind that the difficulties which attend perseverance in acknowledged deficiencies of SYSTEM are constantly recurring with increased force, whilst those which attend its correction gradually subside.

SECTION II.

THE GENERAL PRINCIPLES OF MANAGEMENT UNDER WHICH CONSTRUCTIVE OPERATIONS IN CONNECTION WITH STEAM SHIPPING AFFAIRS HAVE BEEN PROSECUTED, HAS AFFORDED NO GUARANTEE FOR THE PROGRESSIVE IMPROVEMENT OF STEAM SHIP PERFORMANCE, WITH REFERENCE TO THE POWER EMPLOYED.

THE introduction of any new system, demands an exposition of the presumed errors and deficiencies of the previous practice which it is purposed to remedy; it, therefore, in the first place, appears necessary to investigate whether steam ship CONSTRUCTION has been prosecuted on principles of management conducive to the realization of *progressive improvement* in steam ship locomotive performance, based on the results of *previous experience*.

Under the SYSTEM of management which has been pursued, the steam shipping interests generally, both commercial and national, have encouraged and fostered the rivalry of all the principal manufacturers in the country, as Marine Engine CONSTRUCTORS, expressly with a view to the introduction of improvements, and avowedly so, in preference to demanding original plans of engine arrangement, from the professional engineers exclusively employed in their respective interests.

Doubtless the engineer immediately in charge of the interests of steam shipping proprietors, is required, on new contracts being entered into, to give general instructions as to the objects contemplated, to examine into the merits of the plans submitted by the rival manufacturers, and to select the most approved design; also, to assist in maturing it, and ultimately to express his approval of the selected and matured plan:—but such revision and ultimate approval of the plans of others, is not admitted, or felt, to involve the full responsibility which attaches to *originality* of design, although on the occurrence of subsequent difficulty, it has invariably been found to limit the responsibility of the contractor, simply to the effective execution of the specific and approved work which he undertook to perform.

Under this system the engine may be good, and a ship may be well arranged, but the mere production of a steam engine that will work well, and of a steamer fit for sea, falls far short of the engineering duty which attaches to the charge of a steam FLEET:—it does not embrace the consideration of general effective COMBINATION, a condition essential to the constitution of a co-operating "FLEET," but for the realization of which, under the system referred to, the most important functions of the engineer presumed to be in charge, are virtually superseded, and all *responsibility* for carrying out the essential principle of general combination becomes compromised.

This system of management, imposing absolute reliance on the engine manufacturer in the incompatible capacities of consulting engineer (not paid as such),—constructing engineer (not paid as such),—and contracting engineer, undertaking the execution of his own plans at his own price, (for the execution of the selected plans thus elicited and adopted are, of course, never submitted for the competition of the rival manufacturers,) has been publicly sanctioned, even under *parliamentary investigation*, on the ground and with the expressly avowed object of thereby progressively increasing the effectiveness of steam ship performance. Such has been the SYSTEM, and what has been the result? Although the rivalry of manufacturers has been conspicuous in the endless variety of plans on which marine engines have been adopted, and are still being introduced, nevertheless, during the past ten years, it appears that the later productions of marine engine constructors have not surpassed, as regards effective duty, the engines of previous date, and substantially it may be asserted, that under the influence of the system which has been pursued by steam ship directors generally, progressive experience has not afforded that *guarantee* for progressive improvement, or that assured certainty of effective result in the locomotive performance of steam ships, that might reasonably be expected to attend the progress of such weighty affairs, conducted, as they are professed to be, on the trustworthy principles of science.

Such an announcement in the costly matter of marine engines, involving, in many cases, an outlay of from twenty to thirty thousand pounds on the engines of a single vessel, if asserted on no other authority than that of individual opinion, would be generally regarded as incredible; and no authentic records having been kept of the results of steam ship performance in the commercial service, accompanied with all the numerous constructive particulars, both as regards vessels and machinery, necessary for the purpose of scientific deduction therefrom; or at least, such data, if kept, not having transpired, there might have been no means of practically investigating the subject, by the corrective test of actual experience. Fortunately however, the desideratum has been otherwise supplied; not only have PARLIAMENTARY RETURNS and various other publications presented tabular statements of the constructive dimensions and working properties of the steam ships of the British navy, but also a complete record of the Admiralty screw ship trials has been drawn up, and circulated with a view to the prosecution of scientific research: it is therefore purposed to analyze the record referred to, with a view to determine how far the above affirmation is borne out by practical experience.

These documents embrace all the constructive particulars in regard to the vessels, engines, propellers, and numerous other details of circumstantial information, necessary for a complete review of the progress of screw propulsion in the British navy. Forty-four ships are embraced in the screw ship record, and no less than seventy-five sea trials are minutely particularized, and in the case of twenty-one different ships, the performance of each vessel has been investigated, and a series of index numbers deduced, *"shewing the relative performance of the respective vessels."* It must however be observed that the *"performance"* here referred to, relates only to the locomotive properties of the vessels with reference to the engine power actually exerted, the cubical displacement or weight of the body moved, and the rate of speed obtained; and that it does not embrace the general capabilities of the ships in the various other respects on which complete effectiveness and adaptation for service may be dependant.

On the authority of the published record above referred to, and subject to the foregoing explanation, as to the recorded *performance* of the vessels, the annexed Table, No. 1, presents those particulars of information which bear immediately upon the subject of our present enquiry; the twenty-one vessels of which the relative performance has been deduced, are here ranked in the order of the numbers *assigned to them respectively by the authorised record* as shewing "the relative performance of the vessels," the calculation or deduction of the respective numbers being based on received mathematical formula, embracing the engine power actually exerted, the ships' displacement, and the speed attained, when on trial.

TABLE No. 1.

Numbers shewing the relative performance of the Vessels.			Vessels.	Date of Contract.	
1	Highest	218	Rattler...............	Sept.	1841
2	Ditto ...	207	Reynard	August	1847
3	Ditto ...	198	Fairy..................	Nov.	1844
4	Ditto ...	184	Plumper	August	1847
5	Ditto ...	183	Rifleman (refitted)	January	1848
6	Ditto ...	182	Vulcan	April	1847
7	Ditto ...	180	Encounter	October	1845
8	Ditto ...	166	Arrogant.............	October	1845
9	Ditto ...	160	Archer	Nov.	1848
10	Ditto ...	154	Dauntless	October	1845
11	Ditto ...	149	Phœnix	Dec.	1842
12	Ditto ...	148	Niger	October	1845
13	Ditto ...	145	Sharpshooter........	August	1845
14	Ditto ...	132	Conflict	October	1845
15	Ditto ...	123	Teazer ... (refitted)	Nov.	1847
16	Ditto ...	123	Termagant...........	October	1845
17	Ditto ...	115	Dwarf..................	May	1842
18	Ditto ...	112	Minx	Sept.	1845
19	Ditto ...	91	Ajax	October	1845
20	Ditto ...	83	Amphion	June	1844
21	Ditto ...	41	Blenheim	October	1845

Now, in the first place, let us take the five vessels of which the performance has been the highest, as indicated by the column of numbers headed "Numbers shewing the relative performance of the vessels,"—and observe the dates when the engines were contracted for.

EXTRACT FROM TABLE No. 1.

Numbers shewing the relative performance of the Vessels.			Vessels.	Date of Contract.
1	Highest	218	Rattler	Sept. 1841
2	Ditto ...	207	Reynard......	August 1847
3	Ditto ...	198	Fairy	Nov. 1844
4	Ditto ...	184	Plumper......	August 1847
5	Ditto ...	183	Rifleman.....	January 1848

We thus find, on comparing these five vessels, that the vessel whose performance is recorded as the *highest* on the scale, was contracted for in 1841, and that the vessel whose performance stands fifth on the scale, being the *lowest* of the five vessels referred to, was refitted in 1848.

Again, let us now refer to the whole of the twenty-one vessels, as ranked in the order of the tabular numbers which indicate their relative performance, and see from the general *yearly averages* of results, how far our improvement, in screw ship construction has been year by year progressive, and approximately corresponding to the increased experience gained on the subject from the variety of plans successively introduced. The result is as follows:—

TABLE No. 2.

DEDUCED FROM TABLE 1.

Years.	Engines Contracted for.	Order of Performance of the 21 Vessels.
1848	2 Engines ...	5 and 9
1847	4 Engines ...	2, 4, 6, and 15
1846	None	
1845	10 Engines ...	7, 8, 10, 12, 13, 14, 16, 18, 19, and 21
1844	2 Engines ...	3 and 20
1843	None	
1842	2 Engines ...	11 and 17
1841	1 Engine ...	1

Thus it appears that the "Rattler," the original screw ship in the British navy, and the only ship contracted for in 1841, has not been equalled, as regards locomotive performance, with reference to the power employed, by any of its successors, and that the two vessels constructed in 1848, rank only as the fifth and ninth on the list of relative performance, being below the productions of the years 1841, 1844, and 1847.

It may, however, be observed, that the engines of the "Rattler" and "Phœnix" are of a construction not favourably adapted for ships of war, being too high. It is not admitted that this will, of necessity, materially benefit the mechanical performance of the engines; but still, as the engines of all the other vessels on the list of comparison, have been constructed with a view to being as low as possible in the respective vessels, it will therefore be satisfactory to ascertain the relative performance of the vessels so constructed in successive years, excluding "Rattler" and "Phœnix" from the list. Also, "Dwarf," may be regarded as exceptional.

The comparative statement will then stand as follows :—

TABLE No. 3.

DEDUCED FROM TABLE 1.

Years.	Engines contracted for.	Numbers shewing the relative performance.	Average of performance.
1848	2 vessels, viz.		
	Rifleman	183	171
	Archer	160	
		2) 343	
		171	
1847	4 vessels, viz.		
	Reynard	207	174
	Plumper	184	
	Vulcan	182	
	Teazer	123	
		4) 696	
		174	
1846	None		
1845	10 vessels, viz.		
	Encounter	180	129
	Arrogant	166	
	Dauntless	154	
	Niger	148	
	Sharpshooter	145	
	Conflict	132	
	Termagant	123	
	Minx	112	
	Ajax	91	
	Blenheim	41	
		10) 1292	
		129	
1844	2 vessels, viz.		
	Fairy	198	140
	Amphion	83	
		2) 281	
		140	

From which statement it appears, that the average performance of the two screw ships contracted for in 1848, was *inferior* to the average of the four vessels previously contracted for in 1847. That the average performance of the four ships contracted for in 1847, was superior to the average of the vessels contracted for in the previous years, but was not maintained in the vessels subsequently contracted for in 1848. That the average performance of the ten ships contracted for in 1845, was *inferior* to the average of the two ships of the previous year 1844, and it is remarkable that one of the two ships of 1844, the "Fairy" has been found *superior* to fifteen out of the sixteen ships contracted for in the *subsequent* years 1845, 1847, and 1848.

Again, let us examine the matter not by a general comparison of the whole of the vessels, but by *classifying* the ships according to their TONNAGE, and see, as regards *each class* respectively, whether progressive experience has afforded a guarantee for progressive improvement. With this view we will classify together the different descriptions of vessels in the following order:

1st.	Vessels of about	300 tons.
2nd.	Vessels of about	500 tons.
3rd.	Vessels of about	1000 tons.
4th.	Frigates of about	1700 tons.
5th.	Guard ships of about	1800 tons.

And, as the published Records before referred to, embrace the tonnage of the different ships, we are enabled to complete the classification as follows:

TABLE No. 4.

Tonnage.		Vessels.	Numbers shewing the relative performance.	Date of engine contract.
	Tons.			
Vessels of about 300 tons.	312	Fairy	198	Nov. 1844
	296	Teazer	123	Nov. 1847
	303	Minx	112	Sept. 1845
			3)433	
		Average	144	
Vessels of about 500 tons.	516	Reynard	207	August 1847
	490	Plumper	184	August 1847
	486	Rifleman	183	January 1848
	503	Sharpshooter	145	August 1845
			4)719	
		Average	180	
Vessels of about 1000 tons.	888	Rattler	218	Sept. 1841
	953	Encounter	180	October 1845
	970	Archer	160	Nov. 1848
	809	Phœnix	149	Dec. 1842
	1072	Niger	148	October 1845
	1038	Conflict	132	October 1845
			6)987	
		Average	165	
Frigates of about 1700 tons.	1764	Vulcan	182	October 1845
	1872	Arrogant	166	October 1845
	1569	Dauntless	154	October 1845
	1574	Termagant	123	October 1845
			4)625	
		Average	156	
	1474	Amphion	83	June 1844
Guard ships of about 1800 tons.	1761	Ajax	91	October 1845
	1832	Blenheim	41	October 1845
			2)132	
		Average	66	

From the foregoing table it is observable:—

1st. As regards the vessels of about 300 tons, the "Fairy," constructed in 1844, was superior to the two vessels, "Minx" and "Teazer," of the subsequent dates 1845 and 1847.

2nd. As regards the vessels of about 500 tons, the two vessels "Reynard" and "Plumper," constructed in 1847, were both of them superior to the "Rifleman" as subsequently fitted in 1848.

3rd. As regards the vessels of about 1000 tons, the "Rattler," constructed in 1841, was superior to all others of subsequent dates. The "Phœnix," constructed in 1842, was superior to two out of the three vessels constructed in 1845, and the "Encounter," constructed in 1845, was superior to the "Archer," constructed in 1848.

4th. As regards the frigates of about 1700 tons, the four frigates constructed in 1845 present a considerable discrepancy, and the record does not afford the means of comparing them with frigates of a subsequent date.

5th. As regards the guard ships of about 1800 tons, both these ships appear to have been constructed in 1845, and the record affords no comparison with similar ships of subsequent date; but the numbers which indicate their comparative performance present a remarkable discrepancy of about 100 per cent.

It is worthy of remark, as an indication of the general applicability of the principles on which the "numbers shewing the relative performance of the vessels" have been calculated, that if we exclude "Amphion," "Ajax," and "Blenheim," as being manifestly of exceptional construction, we shall find that the indicated *differences* of performance between the largest and the smallest classes, viz., between the 1700 ton frigates and the 300 ton vessels, is not so great as the difference between the highest and lowest performance of vessels of each particular class, for example—(See Table No. 4.)

The average performance of the 1700 ton frigates	156
Ditto of the 300 ton vessels	144
Difference	12

But the difference between the highest and lowest performance of vessels of the same class is as follows:—

300 ton vessels	Highest	198
	Lowest	112
	Difference	86
500 ton vessels	Highest	207
	Lowest	145
	Difference	62
1000 ton vessels	Highest	218
	Lowest	132
	Difference	86
1700 ton frigates	Highest	182
	Lowest	123
	Difference	59

The above applies exclusively to screw ships. No corresponding statement of the *"relative performance"* of paddle wheel steamers has been published by authority, and therefore, no such conclusive illustration can be presented in regard to the yearly average advancement or retrogression of steam ship performance, in connection with paddle wheel propulsion.

It is further to be remarked that the *differences* of performance of the various vessels as shewn by the foregoing statements, may not be *solely* attributable to the constructive differences in the engine department,—the build of the vessel is also involved, and there is reason to expect that the differences *in build* will be found to affect the results, even more than the differences of engine and *machinery* arrangements;—but our present enquiry concerns the general result as it affects STEAM SHIP PROPRIETORS, and not whether the ENGINEER or the SHIPBUILDER has been the most happy in the constructive duties of their respective departments. The immediate subject of our argument, is, whether or not, under the present SYSTEM, *progressive experience* has afforded a satisfactory guarantee for *progressive improvement* in the locomotive performance or duty of steam ships, with reference to the power employed.

Under the circumstances of the above exposition, may it not be concluded, that the continued rivalry of the manufacturing talent of the country, however fruitful in *new forms* of engine construction, affords no guarantee of a progressively improving steam ship performance, corresponding to the means employed?—Is it not sufficient that upwards of A THOUSAND marine engines of different designs, arrangements, and sizes are now in operation, and that no admitted superiority in respect to working efficiency has been achieved, such as to induce the general adoption of any one plan, or even of any one principle of construction in preference to others? and is it not therefore advisable that the course of procedure, or system of direction, under which such indiscriminate engineering has been introduced and is still being continued, should be at least investigated? But, without raising any question as to the IMPORTANCE of the varied *experimental knowledge* that has thus been obtained, it may be observed, that experimental experience is of value, only in proportion as it may induce investigation and lead to improvement.—Under these circumstances it is submitted, that the experience which has been acquired, may be beneficially realized, by being made available as a guide to reformation, in so far as it will lead to the discovery and to the adoption, of those principles which conduce in the highest degree to *predetermined certainty* of result, in the constructive prosecution of the enormously expensive operations in which steam shipping interests are so deeply involved.

SECTION III.

EXHIBITION OF 1851, A FAVOURABLE OPPORTUNITY FOR DRAWING ATTENTION TO SUBJECTS OF SCIENTIFIC ENQUIRY.

ENGINE PROPOSED TO BE EXHIBITED AS A PRACTICAL ILLUSTRATION OF A PLAN OF CONSTRUCTION, ADAPTED FOR ENGINE CLASSIFICATION.

ENGINE CLASSIFICATION ADMITS OF BEING PROGRESSIVELY INTRODUCED; AND DIFFERENT COMPANIES ARE INDEPENDANT OF EACH OTHER, AS TO THE PARTICULAR SYSTEM OF CONSTRUCTION THAT EACH MAY ADOPT.

It being thus apparent that the system of exclusive reliance on the rivalry of manufacturers in the matter of marine engine construction, has not fulfilled the desired purpose of progressive improvement in steam ship performance with reference to the power employed, it is now purposed to explain the course of procedure whereby it is submitted that marine engine efficiency will be more uniformly and more effectively obtained.

The Exhibition appointed to be held in London this year, 1851, for the purpose of bringing into juxta-position, the relative stages of advancement which different nations have attained in the prosecution of the Arts and Sciences, will be an occasion peculiarly directing public attention to the further development of the striking characteristic of the Age, "Practical Utilitarianism;" it therefore appears to be a favourable opportunity for publishing, and more generally promulgating, an exposition of the grounds on which it is sought to systematize and classify the mechanical equipment of steam fleets.

The CLASSIFICATION of the mechanical equipment is regarded as the *fundamental process* on which steam ship management, to be complete, must be necessarily based, and, therefore, it is looked to as the primary and essential means, whereby the all powerful subserviency of steam to marine operations, whether commercial or national, may be rendered more completely effective.

In pursuing this enquiry with a view to the deduction of a definite and practical system of classified engines, it will be necessary to bring under consideration, the respective branches of engineering practice which are involved in the construction of the marine steam engine.—For instance—

1st.—Whether the SWAY-BEAM or the DIRECT-ACTION principle of engine construction is the more suitable for general service.

2nd.—Whether the FLUE, or the TUBULAR boiler, is the more effective, and whether the respective excellences of both may not be combined.

3rd.—Whether the PADDLE WHEEL or the submerged SCREW PROPELLER be generally the better adapted for steam ship propulsion; or, whether they be respectively adapted for special service only.

4th.—Whether the DIRECT OR MULTIPLE GEAR system of connection give the best result as regards the locomotive performance of the vessel with reference to the power employed.

5th.—Whether the efficiency of the machinery department, as regards the performance of the vessel, be affected by variations of the LENGTH OF STROKE and what limit, as regards length of stroke, conduces to the best result.

It is purposed that these enquiries be prosecuted not by dependence on theoretical speculations, but that they be based on the most authentic records of steam ship experimental trials that have been collated up to the present time, viz., the published record of screw ship trials of the Royal Navy previously referred to; and although, as before stated, the differences of ship performance therein announced may not be solely attributable to the differences of the engine and machinery arrangements of the several ships, but also involve the differences of build, still as our conclusions will be based, not on the performance of single vessels, but on the resultant *averages* of classes, it may be expected that these investigations will approximately tend to the elucidation of the subject.

Such is the course of examination, by which it is now purposed to deduce some definite principle and arrangement of engine construction, as especially adapted for being constituted the base of a classification system, and in pursuance of which enquiry, a pair of marine engines has been constructed of about 25 horse power, as a practical illustration of the general PRINCIPLE of the mechanical arrangement thus deduced, thereby also affording the means of testing its merits by actual service at sea; such test being indispensable for the satisfactory solution of the enquiry.

In pursuance of this subject, the pair of 25 horse power engines, above referred to, has been forwarded for public inspection at the London Exhibition of 1851, in illustration of the *principle* of the proposed design, but the details of which are reserved for being still further matured, should the principle be approved.

It may, however, be here observed, that the plan of engine construction thus referred to, does not aspire to any exclusive or singular excellence, as a moving power, which may not be attained by various other plans of marine engine construction, nor is it adduced to claim merit merely for invention in the constructive details of its parts; but it is brought forward with the paramount object of presenting a practical example of an engine, adapted to the general purpose of steam ship propulsion, whether by the *paddle wheel* or by the *screw propeller,* arranged on principles which experience appears to indicate as being conducive to efficiency, as will subsequently be shewn; and constructed within the limit of *height* to which the machinery of ships of war is usually restricted; thereby constituting the *fitness* of the plan for being made the base of a CLASSIFIED REGULATION SYSTEM.

By these means, it is hoped to be made apparent, not only that engine classification is *practicable,* but also, that it admits of being planned without any appreciable sacrifice of engine efficiency, as compared with engines constructed expressly for the particular ships to which they have been fitted.

The practical adoption of this proposed construction of engine would of course be dependant on its *proved* efficiency. With this view it is intended to test the engine, not only with reference to the general object of its construction, viz. *adaptation for classification,* but, also, as to its working properties as compared with any of the numerously diversified plans of engines which have been hitherto produced and now in use, and which have been specially constructed for the particular vessels to which they have been applied, with a view to their operating with the best effect.

To carry out this purpose of general comparison, it is intended that the engines referred to, be erected, and put regularly to work, on board a merchant vessel, and that the data be duly recorded, which will afford the means of comparing the working properties of these engines, with the working properties of the engines of any other vessel that may be selected for comparison.

In addition to the usual tests, whereby the respective working properties and capabilities of engines of different constructions are proposed to be compared with the engine above referred to, it is purposed to embrace any other tests which may conduce to the desired object of determining on the arrangement of engine most suitable, on the whole, for being adopted as the base of a Regulation System. No predilection for the particular plan of engine now submitted is entertained by its author; it is admitted that various constructions of engines are available for the attainment of the object in view; and, moreover, as regards the introduction of classification, it is not held to be necessary, (however desirable it may be) that all commercial companies should apply the same system to their respective fleets. The general adoption of the same system is not essential; each FLEET of merchant steam ships under independent direction, may, if so preferred, be regulated by its own system: it may, however, be remarked that merchant steamers is fitted in exact conformity with the plans that may be adopted in the National Steam Fleet, would be especially adapted for Government Service in times of emergency, and be appreciated accordingly, but this is a commercial consideration, which, doubtless, would not be disregarded. It may also be observed, that the introduction of classification would be *progressive*, and would soon become sensibly felt, if adopted on all available occasions of extension and refitment; and as to the practicability of producing duplicate engines from the regulation drawings, if *judiciously designed* with that view, (for much will depend on that) it may confidently be affirmed that the rivalry of manufacturers will supersede all apprehensions; the authorized drawings of the classified engines will be followed with confidence, like that reposed in the Government charts.

Possibly, however, future modification in detail may occasionally be found advisable, but this will greatly depend on the care bestowed in designing the original production, and it is not conceded that this admission of future possible amendment in detail, justifies the eternal continuance of non-coöperative disorganization; and seeing that upwards of ONE THOUSAND different constructions of engines have been adopted in the service of Great Britain, of which there are about one hundred and fifty in the royal navy alone, and that almost every engine hereafter to be made, if not restricted to some system or systems of classification, will be a continuation of the same unregulated course;—reflecting moreover, that up to the present time, no one plan of engine of modern date has been found to possess any acknowledged degree of *working superiority* over all other engines, or, indeed, above the engines which were made twenty years ago; considering also that during the past twenty years, none of the various arrangements which have been invented, have conduced to *economy* of cost, but that on the contrary, the cost of marine engines has been maintained, notwithstanding the improved facilities which have been invented for their manufacture;—under these circumstances, does it not appear advisable to consider the propriety of continuing such a course of implicit and exclusive reliance on the rivalry of manufacturers, in matters of engine *adaptation* and *design?* and does not our recorded experience of the deficiencies of this practice destroy all hope of its future success?

Marine steam machinery, with its attendant accompaniments of engineers, drivers, stokers and trimmers, now constitute a prominent and constantly increasing branch, both materially and personally, of national marine appliance, analogous to the guns, carriages, harness, and outfit, which constitute the artillery service so important a branch of every effective military force; but what degree of efficiency could be expected from an heterogeneous artillery and ordnance? with guns, no two of the same calibre, and without system in the construction of the carriages, harness, and other equipments; could there be effective discipline in such a force? In like manner, may not the question be asked, what degree of efficiency can be expected from an heterogeneous steam fleet, when put to the test of ENERGETIC RIVALRY in the arts of commerce or of war? would not a defectively systematized steam fleet be found wanting in many points of efficiency, which ESTABLISHMENT REGULATION in the details of equipment, combined with *discipline* in the use and management of it, can alone effect? In all other descriptions of combined action, and particularly so in military science, it is acknowledged that system and discipline can never be too complete; why then should the steam ship service be regarded as an exception to the general rule? The antagonisms which affect Britain in marine affairs are twofold, viz., commercial and national; but the hopes that are founded on the commercial rivalries of peace, are even more stimulating than the apprehensions which may be entertained from the rivalry of war, and of primary importance, in so far that the *means* of prosecuting WAR, are dependent on *success* in the pursuits of COMMERCE. Hitherto commercial prosperity, the base of national power, has been gained chiefly by personal industry and attentive vigilance, and success in war has been mainly attributable to the innate personal attribute of undaunted perseverance; but when MECHANICAL SCIENCE shall become chiefly instrumental in controlling maritime operations, as is now threatened by the introduction of steam, the influence of the *personal* qualities, for which Britain is so noted, will be the less prominently effective, and maritime power based on the *effective use* of STEAM, not on *personal* prowess, will then constitute the chief element of national pre-eminence. These are considerations on which it behoves Britain to be on her guard, that she be not *forestalled* in maritime improvement, and that she assume a position as pre-eminent in the application of mechanical science in nautical affairs, as she has hitherto been in the manifestation and practice of personal industry, perseverance, and courage.

SECTION IV.

ENGINES CONSIDERED.

CAUSES WHICH HAVE CONDUCED TO THE GREAT VARIETY OF DISSIMILAR ENGINES.

OPINIONS OF PRACTICAL ENGINEERS IN CHARGE OF STEAM SHIPS AS TO THE RELATIVE MERITS OF SIDE-LEVER AND DIRECT-ACTION ENGINES.

THE principles of construction which have been adopted for marine engines are of two kinds, designated the side-lever or *sway-beam* construction, and the *direct-action* construction.

The side-lever plan, though not that on which marine engines were first of all constructed, became, at a very early period generally introduced, and it established itself for many years as the standard plan of construction. Thus the *side-lever* engine was early recognized and may be said to have been universally preferred; the relative proportions of its respective parts became approximately defined, but no attempts were made to *classify the sizes* applied to marine purposes, by adopting any progressive scale of increase, either as regards diameter of cylinder or length of stroke; moreover, engine makers studiously devised and appropriated *different* styles of design as peculiarly their own, and purposely so, with a mercantile view to the subsequent repair of the engines of which they alone held the patterns, as well as with a view to the REPUTATION which each manufacturer sought to attain, by the superior excellence that he may have conceived to attach to his own design,—consequently no two marine engines by different makers were alike. The progressive development of steam as applied to mercantile enterprise, combined with a superior build of vessel, achieved a constantly increasing rate of speed, and no adaptation of steam ship build and of engine appropriation thereto would satisfy prospective views. Improvements in the build of vessels with a view to greater speed, and increased engine power in proportion to the ship's tonnage, were consequently progressive. The increase of space in proportion to increased power which was constantly demanded for the machinery department, and the corresponding increase of weight of the machinery itself, in proportion to the tonnage of the vessel, became considerations which required the utmost attention of steam ship constructors. Engineers in consequence made it their study to economise the size and weight of the marine engine, and reverting to the principle of direct action, which had been commonly adopted for land purposes, and applying that principle of engine construction to steam boats, it was at once found practicable to devise a variety of arrangements on the *direct-action* principle, each to a certain extent effecting the object of reduced weight and space in proportion to nominal power; and such engines having specially attracted the notice of steam shipping interests, all the engine makers in the country of any note, speedily devised, introduced, and appropriated, their respective designs of DIRECT-ACTION engines, the engines of the rival manufacturers characteristically differing from each other, for the reasons before referred to when accounting for the diversified plans of side-lever engines. And again, of late years, the application of the SCREW PROPELLER has been regarded as an occasion for the introduction of *another series* of engine arrangements, which all the principal engineers of the country have availed themselves of, and produced their respective plans of engines adapted for *screw* ships, distinctive from those applied to *paddle wheel* vessels.

It may not be irrelevant to observe, that, notwithstanding the reduced weight and asserted simplicity of *direct-action* engines, their introduction was not based on constructive economy, but on the contrary, the combined qualifications of *light weight* and *contracted size*, appear to have been made the condition of preference in the estimation of steam ship proprietors;—this state of things was certainly encouraging to engine manufacturers, they readily prepared themselves to supply the choice of engine which the market required, and it behoved the purchasers rather than the sellers of engines, to determine for themselves the relative fitness for their own purposes, of the side-lever and direct-action engines thus offered to their option at about equal cost.

What, now, after many years of experience, is found to be the result, at the present day, of the diversities of engine design which have been so much lauded as the inventions and improvements of modern times in marine engine construction? The fact is, that, on comparison of fair examples of each and all of the diversified plans above referred to, the difference of effect with which the side-lever and direct-action principles respectively perform the essential functions of the steam engine, is so small and inappreciable, that parties of the greatest experience as marine engine manufacturers and as steam ship proprietors, have not arrived at any *conclusive* decision,—the advantages of decreased weight and saving of space derived from the direct-action plans of construction, appear to have been counteracted by the greater amount of friction, and other practical objections to which such engines are subject.

Modern inventions have wonderfully increased the facilities for the improved manufacture or production of steam engines, particularly of engines of large size, but, as regards the working functions of the steam engine itself, no generally recognised improvement has been effected;—nothing has been done beyond producing a display of superior workmanship and of *inventive ingenuity* in matters of arrangement, whereby, in divers manners, as above referred to, the construction of engines has been made conformable to the distinctive views of different manufacturers. The relative degrees of *mercantile* preference due to side-lever and direct-action engines, has defied all satisfactory solution; different parties of the greatest experience on the subject, entertain different shades of opinion; even mercantile scrutiny has failed to determine the enquiry, for in the practice of some of the most successful steam ship enterprises of the present day, the SIDE-LEVER principle of construction is still preferred, as in the Halifax line of mail packets; whilst the DIRECT-ACTION principle has been adopted by others, as, for instance, by the Peninsular and Oriental Company. But from the difficulty of ascertaining which of the two principles of engine construction is best entitled to mercantile preference, it must not be inferred that the upholding *expenses* actually incurred by both, respectively, are of a trivial nature; by the parliamentary evidence of the highest authorities on this point, it appears to have been conclusively established, that the cost of upholding steam ship machinery has of late years amounted, on the average, to about £6 per horse power per annum, being about 12 per cent. per annum, on the prime cost of the machinery, which annual outlay, is but one of the grand points of current expense in which steam ship proprietors are concerned, and which a *complete system of* CLASSIFIED CONSTRUCTION would do much to remedy.

The foregoing remarks are confirmed by the published record of the investigations of the parliamentary committee on the navy estimates of 1848, the evidence referred to being that of the highest authorities; the investigation, however, did not embrace the evidence of that class of engineers who are practically intrusted with the actual working charge of marine engines: This latter class are generally men whose judgment has been matured in the severe school of practical experience, and whose opinions, therefore, are highly deserving of consideration on such an occasion, which has baffled their superiors in position. What, then, are the sentiments of the working engineers in the steam ship service of Britain, both mercantile and national, on the general question of the *comparative merits* of the side-lever and direct-action principles of marine engine construction? There is every reason to conclude, that by far the greater number give a decided preference to the *constructive principle* of the old sway-beam engine, as being the most conducive to trustworthiness, facility of management, and general working economy.

With such opinions in favour of the sway-beam principle, backed by its continued use in the service of some of the principal mercantile companies, it may not yet be regarded as having been superseded by the diversities of direct-action arrangements, which have been of late years introduced; but the principle of the SWAY-BEAM engine may be ranked as still worthy of consideration, in connection with the important subject of marine engine construction, with a view to the introduction of CLASSIFICATION.

In the construction of the pair of 25 horse power engines, before referred to, the SWAY-BEAM principle has been adopted, but the ordinary arrangement has been modified to meet the object of applicability *either* to the *paddle wheel* or to the *screw propeller,* thereby adapting the sway-beam principle of construction for being made the base of a CLASSIFIED SYSTEM.

SECTION V.

BOILERS CONSIDERED.

THE PRACTICAL OPERATION OF FLUE AND TUBULAR BOILERS EXPLAINED.

PRACTICABILITY OF CONSTRUCTING BOILERS SO AS TO AVOID THE APPARENT DEFECTS AND COMBINE THE RESPECTIVE EXCELLENCES OF THE FLUE AND TUBULAR PRINCIPLES OF CONSTRUCTION.

THE boiler department of steam ship service is constructively independent of the engine department, the duty of one being simply the production of steam, and the duty of the other the production of moving power by the agency of steam; but in considering the subject of engine construction with a view to definite classification, it is of the highest importance that boiler construction be also embraced, as steam ship *economy* is mainly dependant on efficiency in the boiler department, and the dimension of the boiler in regard *to height*, becomes a consideration which will materially affect the *choice* of engine arrangement applicable to ships of war. It is therefore purposed briefly to elucidate the constructive principles on which the efficiency of marine boilers is conceived by the author to be greatly dependant.

Two kinds of boilers have been applied to the service of steam vessels, distinctively known as the "FLUE" boiler and the "TUBULAR" boiler; and, as we have seen in the case of engines, that no decided superiority has been ascertained in point of working efficiency between the side-lever and the direct-action engines, so, in the case of boilers, it is found that the same doubts prevail as to the *relative merits* of the FLUE and TUBULAR principle.

It is universally acknowledged that boilers of equal steaming power can be made to occupy the least cubical space on the tubular plan of construction, but it is also admitted that flue boilers are the most easily managed, in so far that they do not demand such constant and close attention, to prevent the serious derangements liable to occur in tubular boilers, if not carefully attended to, from the comparatively small quantity of water which they contain, and consequently from the more rapid changes of condition to which they are subject.

A diversity of opinion, however, exists as to the relative *quantities* of steam which the flue and tubular boilers will produce from a given consumption of fuel; and also, as to their relative durability, trustworthiness, and upholding cost; in short, it has not been agreed which of the two kinds of boiler is entitled to mercantile preference, and in the practice of the commercial steam ship fleets previously referred to, *both kinds of boilers are still in use,* it being found, generally, that the advocates for the sway-beam engine still adopt the flue in preference to the tubular boiler.

The boiler department, however, involves considerations of the most vital importance in steam ship management; it not only swallows up the greater portion of the upholding cost, which was before alluded to, and estimated at 12 per cent. per annum on the prime cost of the machinery, but boiler derangements are generally the principal cause of steam ship *disability* for service, a loss which scarcely admits of pecuniary estimate; and the quantity of steam capable of being elicited from a given quantity of fuel, greatly depends on the manner in which the boiler, whether flue or tubular, performs its duty;—a consideration of the highest moment in connection with vessels performing long sea voyages, or engaged in foreign service, where the *cost* of coals is *enormous.* In fact, the commercial bearings of the boiler question, are of an importance far surpassing that of the engine, and demands the most searching investigation.

The functions required to be performed by a boiler are of two distinct kinds, viz., first, to effect the perfect *combustion* of the fuel; and secondly, to cause the heat generated by the combustion of the fuel to be duly *communicated* to, or *absorbed* by, the water in the boiler, thereby converting it into steam. In considering these required conditions of boiler operation, it must be observed, that fuel may be *expended* by being passed through the furnaces of a steam boiler without having its *inflammable gasses* subjected to the condition of perfect *combustion;* the burning which takes place in the furnace may be but partial, and do little more than disengage the gaseous proceeds of the fuel, which by themselves will not produce perfect combustion, and which, though not in a state of ignition, may be driven through the flues or tubes, and pass away by the funnel. The first point, therefore, in boiler construction, is, to aim at those conditions which tend to produce the perfect *combustion* of the fuel. The theory of combustion as applied to steam boilers has been so ably treated of and promulgated by various publications, that nothing need be here adduced on the *theorectical* investigation of the conditions essential to combustion. It must, however, be acknowledged that various modes of furnace construction and arrangement which have been suggested for effecting that object, do not appear to have stood the test of general marine practice, though, no doubt, they have drawn much attention to the subject, and thereby materially conduced to the due proportioning, and favourable construction of furnaces. The author's views, as to the most practical mode of realising the conditions essential to combustion in marine boilers, are based on the consideration, that much benefit may be derived from the circumstance, that marine boilers are seldom if ever fitted with one furnace only, but contain two, three, or more furnaces, which are all *simultaneously* in operation. Each one of the furnaces of a marine boiler, *taken by itself*, after being charged with fresh fuel by the common process of firing, evolves for a time so great a quantity of gaseous proceeds, that the limited quantity of *atmospheric air* that gets access through the fire bars, is *not sufficient* to combine with the gases in the due proportions essential to perfect combustion; and, again, after the gaseous proceeds have been in a great measure dispelled, the quantity of air which then gets access through the bars may be *in excess* of the proportion required for effecting perfect combustion; hence, it appears that single furnaces, or furnaces working independently of each other, are frequently in the condition chemically unfavourable to the production of perfect combustion. Various plans have been invented for regulating the supply of fuel and of atmospheric air, so that *both* may be constantly supplied in *the proportion* required for producing the best effect; but, either from complication in construction, difficulty of management, or other defects, these inventions have been generally found to be practically inoperative; and, consequently, the common furnace is almost universally preferred for marine purposes. If, therefore, we take any *one* furnace, it may be in operation for a great portion of its time, under conditions not effecting the *combustion* of the inflammable gases evolved from the fuel,—the admission of atmospheric air will sometimes be deficient, and at times in excess. If, however, we have *two* furnaces in operation, they will not, probably, be both in the same condition at the same time;—*one* may be producing gases in excess of the air admitted, *the other* may be admitting air in excess of the gases produced. If, therefore, we take care so to construct the furnaces that the proceeds of both furnaces shall combine together and become thoroughly mixed, before passing through the flues or tubes, the *combination* of the gases thus produced from the *two or more* furnaces will probably be in a condition much more favourable to proper combustion than would be the case in either one of the furnaces taken by itself, the *deficiency* of atmospheric air in the one furnace being compensated by the *excess* in the other, and in like manner, the greater the number of separate furnaces thus brought together before entering the flues or tubes, the greater chance will there be of the *collectively combined* gases being in a condition favourable to combustion, and by due attention to the firing, the probability of a good result being obtained will be still further increased. Hence, if we take care so to construct the furnaces that the gaseous proceeds from the different furnaces shall become mixed together before they enter the flues or tubes of the boiler, and that every attention be paid to the proper management of the stoking, we shall then have a state of things, so far as the furnaces are concerned, highly conducive to the proper combustion of the fuel and the consequent generation of intense heat. The next consideration is, that the heat thus generated by the combustion of the fuel shall be duly *communicated* to, or *absorbed* by, the water in the boiler. For this purpose, whether the boiler be a flue boiler or a tubular boiler, it will be necessary that the extent of flue or tubular surface in contact with the heat on one side, and with the water on the other, shall be in due proportion to the effect required to be produced, and also that the time during which the current of hot air remains in contact with the flues or tubes shall be sufficient for effecting the required object of communicating its heat to the water, until both are nearly of an equal temperature, and whereby the water may be partially converted into steam. It thus appears, that, in the first place, the heat has to be generated, we may say "*brewed,*" and, in the next place, it has to be communicated to the water,—the first part of the process is dependant on the *furnaces*, the latter on the *flues* or *tubes;* and the perfection of the result depends on both these functions being duly performed.

Let us now see how the usual construction of the flue boiler and of the tubular boiler, respectively, is adapted for fulfilling the distinct conditions above referred to, viz.,—first, for effecting a perfect state of combustion, and, secondly, that the heat so produced shall be duly transmitted to, or absorbed by, the water in the boiler.

In FLUE boilers as usually constructed, it is considered desirable that the run of the flues shall be of considerable length before terminating in the uptake to the funnel, to effect which object, the furnaces are usually made to discharge themselves into a general *receiving flue* as soon as possible, whereby the gases from the different furnaces become *combined* at the very entrance of the flues, and in boilers so constructed, if the firing be well conducted, the *combustion* takes place at the entrance of the flues in a tolerably *satisfactory* manner; the hot air then passes through the flues, the sectional area of which is considerable in order that the draft may not be too much checked, consequently the hot air passes along in mass, a condition of things *unfavourable* to the due *transmission* of the heat to the water, unless the flues be of great length, thereby occupying much space, and requiring that the boiler be of great size. It therefore appears that the flue boiler is favourably conducive to *combustion,* but not well adapted for duly *communicating* the heat to the water in the boiler.

In TUBULAR boilers, as usually constructed, the gases which are evolved from each furnace have direct access to the tubes, no provision is made to ensure that the gases from different furnaces shall become thoroughly combined together *before entering* the tubes, and indeed, in many cases even the partial flowing together of the proceeds of the different furnaces is *prevented* by the furnaces being connected direct with the tube plates: thus by the ordinary construction of tubular boilers, the gases which are evolved from each separate furnace, are liable to pass through the tubes in the various conditions of *imperfect* combustion previously referred to as incidental to single furnaces; but *after having passed through the tubes,* the proceeds from all the different furnaces become collected in the uptake and funnel, and, being there combined and mixed together, they burst into *useless* combustion, frequently making the funnel red hot. In tubular boilers, however, the gaseous proceeds of the furnaces, though in an imperfect state of combustion, are so minutely subdivided in their passage through the tubes, that whatever amount of heat may have been generated, is rapidly communicated to the water, producing a proportional effect in the raising of steam. Hence it appears that the usual construction of tubular boilers is unfavourable to the production of perfect combustion, but very favourable to the due transmission of the partial amount of heat that is produced to the water in the boiler.

Seeing, therefore, that the properties of the flue and tubular boiler, as usually constructed, are characteristically different from each other, it is proposed that a construction of boiler be so devised as to combine the peculiar excellences of both kinds, by adopting the principle of the furnace construction of the flue boiler for *generating* the heat, and the principle of the tubular boiler for *absorbing* it: by thus combining both these principles of construction, the gases produced by various furnaces will be incorporated together, thereby inducing perfect combustion *before entering the tubes,* and the heat thus generated will be communicated to the water, by the agency of the admirable facilities for that purpose which the adoption of tubes is found to afford.

The *principle* of boiler construction being thus determined, classified boilers of three or more sizes, say 50 H. P., 75 H. P., and 100 H. P. may be provided, all the three sizes being of the same length and height, but varying only in width. By this arrangement, any vessel could be furnished with the aggregate amount of boiler power corresponding to the size or class of the engines.

The classified construction of boilers for *ships of war*, will probably differ as regards *height*, from the system best adapted for *mercantile* service, and the general subject of boiler construction *in detail*, with a view to classification, will be more conveniently treated of as a matter of enquiry, distinct from the classification of engines.

SECTION VI.

PROPELLERS CONSIDERED.

THE SCREW PROPELLER NOT A MODERN INVENTION, BUT SUGGESTED AND PATENTED FOR MOVING VESSELS BY MANUAL LABOUR, ANTECEDENTLY TO THE APPLICATION OF STEAM POWER.

EFFECTIVE OPERATION OF THE SUBMERGED SCREW PROPELLER NOT INFERIOR TO THAT OF THE PADDLE WHEEL.

It is remarkable, that in the year 1785, antecedently to the application of the steam engine to the purposes of navigation, a construction of instrument closely analogous to the modern screw propeller, was invented and patented in England, as a means of giving motion to floating vessels; the construction and form of the proposed instrument was described as being somewhat similar to the then well-known form of the surface presented by the sails of a windmill, and at the present day a closer comparison can scarcely be made in order to convey a popular idea of the form and operation of the screw propeller as now applied to steamers. It nevertheless appears, that, in all the experimental efforts that were originally made with a view to the application of steam as the moving power on board floating vessels, the paddle-wheel was resorted to as the most immediately available and self-evident means of applying the power of the engine, and by its aid, the successful application of steam to the propulsion of vessels, gradually became realized; thus a new field of commercial enterprise presented itself, the requirements of which drew insatiably on the mechanical intelligence of the age; experience begat confidence, and gradually extended mens' ideas, as regards the scale on which the well defined principles of the operation of steam, as developed by the agency of the steam engine, could be safely applied to marine purposes;—the practical prosecution of steam ship enterprise singularly manifested the indomitable progress of British perseverance and skill, twenty-five years sufficed to develope the extension of steam machinery up to 1000 horse power, and for embracing the whole Globe within the limit of its locomotive range. Not only have the requirements of commerce been met by the application of steam, but it is now also being made instrumental in promoting the effectiveness of warlike equipment.

In this extended application of steam to ships of war, the importance of having the machinery below the water line of the vessel, and not exposed within the ordinary range of shot, necessarily attracted attention, which, for this and other reasons of great vitality, as respects the armament and arrangements of ships of war, has resulted in the revival of the long-neglected principle of the submerged SCREW PROPELLER. The personal exertion, perseverance and intuitive ingenuity of a single individual, conspicuously promoted the successful course of practical procedure, whereby the *submerged screw propeller,* slowly, but gradually gained ground in public estimation, in opposition to its rival, the *paddle wheel;* and in proportion as the principle of screw propulsion became the more assured of successful issue, the ingenuity of inventors became the more active in the prosecution of its practical detail; suggestions of new forms, and diversified arrangements with a view to the most effectual application of the submerged propeller, have been numerous and may be endless, each variety aiming at some one special point of excellence not attained in others; but suffice it to say, on this subject, that the contour of surface, known as the Archimedean Screw surface, constitutes the base of the whole system; and means having been devised for readily disconnecting the propeller, and even for altering the set of its blades, or the rate of pitch, either with or without disconnecting it from the shaft, the screw propeller may now be regarded as forming an independent portion of the machinery of the ship.

The adoption of the screw propeller in the merchant service is no longer regarded as experimental, and in the Royal Navy alone it has been applied to about fifty vessels. Its operation has been critically compared with that of the paddle-wheel, under various conditions of engine power, and experience has shewn that, under circumstances which admit of the screw propeller being favourably applied, it is equal to the paddle-wheel as an effective means of applying engine power to the propulsion of the vessel. And here, again, in respect to the relative merits of the paddle-wheel and of the screw propeller, we have a similar description of well contested rivalry, to that which has occurred in regard to the relative merits of side-lever and direct-action engines, and also, as to the relative merits of flue and tubular boilers; both modes of propulsion being now in common use. Such appears to be the case at the present time in regard to the applicability of the screw propeller to the merchant service; but for the purposes of *naval armament* which have given the chief stimulus to the introduction of the submerged screw propeller, its advantages are, in many respects, of a nature which do not admit of mercantile estimate, and they are of so decided a character that there can scarcely be a question as to its superior merits in all cases which favourably admit of its application; at the present time both systems of propulsion are adopted, it may be said indiscriminately, both in the merchant service and in the royal navy, but there is undoubtedly, a tendency towards the general adoption of the screw propeller in preference to the paddle-wheel.

Under these circumstances it appears desirable, that any system of engine construction now to be adopted with a view to systematic classification, should be unquestionably well adapted for driving the screw propeller, especially if such arrangement can be effected without any material prejudice to its application to the paddle-wheel; by reference to the example of engine construction now brought forward, and to the description thereof subsequently inserted, it will appear that this double requirement of engine construction is within the ordinary limits of mechanical arrangement, and that in maturing this design of engine construction with a view to its being made the base of a regulation system of CLASSIFICATION, the probability of the preferential adoption of the submerged screw propeller, has been duly and especially regarded.

SECTION VII.

MODE OF CONNECTING CONSIDERED.

INVESTIGATION AS TO THE RELATIVE ADVANTAGES OF THE ENGINES BEING CONNECTED DIRECTLY WITH THE PROPELLER SHAFT, OR CONNECTED BY THE INTERVENTION OF MULTIPLE GEARING.

In the application of the screw propeller, it has been found that the maximum working speed of the engine is much less affected by the variable rate of the vessel's speed when under canvass, than was originally apprehended would be the case, which is supposed to be occasioned by the effect of ships in motion drawing water in their wake, usually termed "dead water," whereby the medium in which the screw operates, is comparatively still water, presenting an approximately constant degree of resistance to the revolving motion of the propeller, the effect thus produced varies in degree according to the difference of build of the ship; but in all cases it is so far operative in practice, that there appears to be no absolute necessity for the application of differential gearing, in order that the working speed of the engine may be adjusted to meet the *variable* sailing rates of the ship. It however remains to be determined, whether the engine, by being connected *directly* with the screw shaft, or by the adoption of *multiple gearing,* produces the best result as regards the performance of the ship.

On the first introduction of the screw propeller, it was prudently applied to vessels of comparatively small size, and consequently the propellers were of limited dimensions as regards diameter, which also restricted the pitch, and rendered it necessary to run the screw at great speed, to effect which object, multiplying gearing was applied. Experience promised success; the submerged screw propeller became gradually applied to larger vessels, admitting the application of screws of greater diameter and of augmented pitch, thus proportionally reducing the necessary number of its revolutions, and at length it was found admissible with ships of considerable size, to connect the engine *directly* with the screw shaft, thus dispensing altogether with multiplying gearing. It must, however, be observed that the attainment of this object was in a considerable degree effected by the device of constructing engines with a *shorter* length of stroke in proportion to diameter of cylinder than usual in marine engines, expressly with a view to their running at a high rate of speed, altogether unprecedented in marine machinery. A considerable number of engines for ships of large size have thus been constructed on the *direct-connection* plan, and various vessels driven by such engines, have attained a rate of locomotive speed, equal to that of similarly built vessels driven by paddle-wheel engines of equal power. There is, however, reason to apprehend that the extremely *coarse pitch* which is required by the direct-connection plan, to give the vessel a high rate of speed, produces *concussions* which are not only inconveniently felt on board, but injurious to the stern of the ship, and that the extreme rapidity of engine stroke required for carrying out the direct connection principle, is a severe test which but few engines can permanently endure; consequently, the plan of direct-action construction has not been invariably followed up, and some of the largest screw steamers which have been recently fitted, have reverted to the adoption of multiplying gearing.

As regards the gear itself, its first application to engines of the great amount of power usual in large steamers, far surpassing as it does the greatest amount of mechanical power ever transmitted through gearing by land engines, or by any known water-power, was a bold undertaking, for which there was no precedent in the construction of millwright work. The first thing to be ensured, was to make the gearing of sufficient *strength*, which paramount consideration induced the abandonment of various well known arrangements necessary for effecting the noiseless operation of gearing; but experience in the application of gearing has overcome all difficulties, and multiplying gearing for screw ship engines of the largest power can now be constructed to work with almost noiseless precision.

The attention of parties most connected with the practice of screw propulsion in the mercantile service, does not appear to have been directed to the collection and publication of the data, necessary for arriving at any decision as to the relative effects of connecting the engine power *directly* with the screw shaft, or by the intervention of *gearing*. Individual opinions have been formed and acted upon, but it has not transpired that such opinions have been based on any scientific investigation of the *results* of screw ship trials: this deficiency of information in regard to mercantile experience of the relative merits of the two modes of connecting the engine with the propeller, has, however, been embraced in the published records of the Admiralty as respects the application of the submerged screw propeller to screw ships in the Royal Navy.

On inspection of this record, with especial reference to the mode in which the engine is connected with the screw shaft, and observing its effect as indicated by the column of numbers shewing approximately the relative performance of the vessels, we collect the following results:—

TABLE No. 5.

Vessels.	Whether connected Direct or by Multiple Gearing.	Numbers shewing the Relative Performance of the Vessels.
Rattler	Multiple 4 to 1	1 Highest ...218
Reynard	Multiple 2 to 1	2 Ditto 207
Fairy	Multiple 5 to 1	3 Ditto 198
Plumper	Multiple 2·5 to 1	4 Ditto 184
Rifleman	Multiple 2·5 to 1	5 Ditto 183
Vulcan	Direct	6 Ditto 182
Encounter	Direct	7 Ditto 180
Arrogant	Direct	8 Ditto 166
Archer	Multiple 3 to 1	9 Ditto 160
Dauntless	Multiple 2·27 to 1	10 Ditto 154
Phœnix	Multiple 4 to 1	11 Ditto 149
Niger	Direct	12 Ditto 148
Sharpshooter.	Multiple 3 to 1	13 Ditto 145
Conflict	Direct	14 Ditto 132
Teazer	Multiple 3·73 to 1	15 Ditto 123
Termagant	Multiple 2 to 1	16 Ditto 123
Dwarf	Multiple 5·15 to 1	17 Ditto 115
Minx	Multiple 4 to 1	18 Ditto 112
Ajax	Direct	19 Ditto 92
Amphion	Direct	20 Ditto 83
Blenheim	Direct	21 Ditto 42

From the above table it appears that the five *highest* numbers indicating the relative performance of the vessels, appertain to vessels of which the screw is driven by the intervention of MULTIPLYING GEAR, and it also appears that the three *lowest* numbers in the list appertain to engines connected *directly* with the screw shaft; which results are not adduced as *proof* in favour of the principle of connecting by multiplying gearing in preference to the direct connection, but as strongly indicating the mechanical advantages of the system.

It is to be observed that this comparison and conclusion is based exclusively upon the constructive properties of the ships and machinery, as indicated by their effect on the relative performance of the vessels, and that it does not embrace the consideration of the more severe *concussion* which the ship sustains by the operation of the direct connection engines driving a *coarse* pitch screw, in comparison of what is occasioned by the multiplying gear driving a screw of *fine* pitch, which consideration, independently of all mechanical preference, forcibly urges the adoption of multiple gearing, whereby screw propellers of comparatively fine pitch become practically available.

Hence it appears that the application of GEARING promises to be the preferable mode of driving the screw propeller, and, consequently, it becomes advisable that any plan of engine that may be proposed as the base of a CLASSIFIED SYSTEM of construction, should be so arranged as to afford *facilities for the application of gearing,* whereby the revolutions of the propeller may be arranged in any required ratio to the revolutions of the engine.

SECTION VIII.

LENGTH OF STROKE CONSIDERED.

INVESTIGATION AS TO THE LENGTH OF ENGINE STROKE THAT HAS BEEN FOUND MOST CONDUCIVE TO THE EFFECTIVE PERFORMANCE OF THE SUBMERGED SCREW PROPELLER.

In marine engine construction for *paddle wheel* steamers, it has been generally considered advisable that the length of stroke should not be less than the diameter of the cylinder; and, in practice, the length of stroke is usually made to exceed the diameter, if the height of the paddle shaft above the vessel's floor, admit of its being done; and by some marine engineers of high repute, paddle wheel engines are made of the greatest length of stroke, not exceeding twice the diameter, that circumstances will admit of.

In the adaptation of engines to the *screw propeller*, it is observable that the general practice above referred to, as applicable to paddle wheel engines conduces to certain conditions disadvantageous to the effective operation of the propeller, for by increasing the length of stroke, we necessarily *decrease* the number of revolutions which the engine can be allowed to make per minute, which decrease of engine revolution involves the necessity for *increasing* the pitch of the screw, or for increasing the multiple of the gearing by which the engine may be connected with the screw shaft. It therefore appears important to determine what *length of stroke* has been found most favourably applicable to engines driving the screw propeller.

The exact ratio in which a decreased length of stroke may be *detrimental* to the working efficiency of the *engine* itself, and the exact ratio in which its available accompaniment of decreased pitch of screw, revolving with increased speed, may be *advantageous* to the operation of the *screw propeller,* scarcely admit of being ascertained by purely mathematical investigation, nor has commercial experience of screw ship operations responded to the enquiry; but the Admiralty Record of screw ship trials gives data which again greatly assist our investigation on this subject, and the case now before us presents another instance forcibly illustrating the use of such records, unfolding as they do, the practical operation of combined mechanical agency, and affording the means of determining approximately the relative degrees in which steam ship performance may be affected by any definite variations of construction, either as regards the build of the vessel, or the mechanical arrangement of the engines.

Referring to the foregoing table (No. 5,) it will be found to embrace eight cases of vessels driven by *direct connection* engines, viz., "Vulcan," "Encounter," "Arrogant," "Niger," "Conflict," "Ajax," "Amphion," "Blenheim," which have been subjected to experimental trial, and in regard to which the numerical deduction of their respective degrees of performance with reference to the power employed, has been elaborately worked out and exemplified, and in respect to which vessels, the respective *lengths of engine stroke* have been recorded, as shewn in the following table:—

TABLE No. 6.

Vessels.	Stroke.		Number and Diameter of Cylinders.
	Feet.	Inch.	Inches.
Vulcan	2	0	4 of 49½
Encounter	2	3	2 of 55
Arrogant	3	0	2 of 55
Niger	1	10	4 of 47⅝
Conflict	2	0	4 of 46
Ajax	2	6	4 of 55
Amphion	4	0	2 of 48
Blenheim	3	0	4 of 52

Now, by selecting and classifying together in column (A) the four vessels which are propelled by the engines of the *shortest* stroke, and in column (B) the four vessels which are propelled by the engines of the *longest* stroke, we have

TABLE No. 7.

(A)	Stroke.		(B)	Stroke.	
	Feet.	Inches.		Feet.	Inches.
Encounter	2	3	Amphion	4	0
Conflict	2	0	Arrogant	3	0
Vulcan	2	0	Blenheim	3	0
Niger	1	10	Ajax	2	6
	4) 8	1		4) 12	6
Average of (A)	2	0	Average of (B)	3	1

From which it appears that we may consider the column (A) as being collectively an average exponent of *two feet* stroke engines, and the column (B) as collectively an average exponent of *three feet* stroke engines. Now let us further refer to the column of Table

No. 5, which shews, by numerical comparison, the relative performance of the vessels referred to; and see what degree of constructive efficiency, with due reference to the engine power employed in each case, has been thereby assigned to the respective ships which constitute the columns (A) and (B).

TABLE No. 8.

Vessels. (A)	Numbers shewing the relative performance of the vessels.	Vessels. (B)	Numbers shewing the relative performance of the vessels.
Encounter	180	Amphion	83
Conflict	132	Arrogant	166
Vulcan	182	Bleheim	42
Niger	148	Ajax	91
	4)642		4)382
Aver. of (A)	160	Aver. of (B)	95

Hence it appears that the average performance of the vessels of column (A), the exponent of the *two feet* stroke is 160, whilst that of column (B), the exponent of the three *feet stroke* is only 95, the superiority being so decisively in favour of the vessels which are driven by the *short stroke* engines, that it becomes desirable to analyze the matter still further, and ascertain in what relative degree the difference of length of stroke, has affected the number of revolutions per minute of the respective engines, and the pitch of the screws, with which they are in direct connection. On these points the record also supplies the following particulars, viz.:—

TABLE No. 9.

Vessels. (A)	Strokes per min.	Pitch of screw. Ft.	In.	Vessels. (B)	Strokes per min.	Pitch of screw. Ft.	In.
Encounter	78	15	0	Arrogant	55	15	0
Conflict	68	16	6	Amphion	45	17	11
Vulcan	55	16	6	Blenheim	43	20	0
Niger	74	17	0	Ajax	48	20	0
	4)275	65	0		4)191	72	11
Aver. of (A)	69	16	3	Aver. of (B)	48	18	3

Thus it appears that the practical operation of the two feet stroke (A) as compared with the three feet stroke (B), admits of the *revolutions* of the screw propeller being increased in the proportion of 69 to 48, and consequently the *pitch* of the screw being reduced in the proportion of 16·3 to 18·3, a change of circumstances so considerable, as to afford strong presumptive evidence, that the superior performance of the vessels denoted by (A), is in a great degree attributable to the reduced pitch of screw, and the increased number of its revolutions, *consequent* on the *reduced* length of stroke of the engines (A) as compared with the stroke of the engines (B).

The result above deduced is remarkable, from the consideration that the engines (A), averaging only *two feet* stroke, have cylinders of the respective diameters of 46, 47⅝, 49½, and 55 inches; and that the engines (B) have cylinders of the respective diameters of 55, 48, 52, and 55 inches, for which sizes of cylinders, even the three feet stroke is considerably within the limit usually adopted in marine engine construction.

The foregoing investigation having been limited to *direct action* engines only, it becomes important to ascertain how far the same remarkable property of short stroked engines being *preferable* to long stroked engines for SCREW propulsion, holds good in the case of engines fitted with *multiple gearing;* and, referring again to the Admiralty Record, we find that it embraces the particulars of no less than thirteen vessels that have been fitted with multiple geared engines, eight of them drawing about ten feet water and upwards, which we will select and classify in the order of their length of stroke, viz.:—

TABLE No. 10.

Vessel.	Length of stroke.		Numbers denoting the relative performance of the vessels.	Average performance.
	Ft.	In.		
Reynard. .	2	0	207	195
Plumper. .	2	0	184	
	2)4	0	2)391	
Aver. stroke	2	0	195	
Rifleman. .	2	9	183	171
Archer. . .	3	0	159	
	2)5	9	2)342	
Aver. stroke	2	10½	171	
Termagant	3	6	122	160
Rattler. . .	4	0	217	
Dauntless.	4	0	153	
Phœnix . .	4	6	149	
	4)16	0	4)641	
Aver. stroke	4	0	160	

Here, again, in the case of multiple geared engines, we find a confirmation of the previous deduction in the case of direct action engines, as to the preference apparently due to a short stroke, for it will be observed, that the two vessels first above classified, with engines of *two feet* stroke, give an average performance denoted by the number 195. The two next vessels with engines of *two feet ten and a half inch* stroke, give a reduced average performance denoted by 171,—and the four last vessels with engines averaging a stroke of *four feet,* give a still further reduced average performance denoted by 160.

Hence it appears that in the case both of direct action engines and of multiple geared engines, the limited stroke of TWO FEET is preferable to a longer stroke for the purpose of *screw propulsion,* a conclusion of apparently trustworthy import, resulting as it does, from the aggregate summary of screw ship trials, embracing ships of every class.

It is also to be observed, that the general performance of the *multiple geared* engines, as denoted by the average of the "numbers shewing the relative performance of the vessels," is superior to the performance of the direct action engines, in a progressively increasing ratio dependant on the *reduced* length of stroke, and that in proportion as the number of revolutions per minute of directly connected engines is increased by a reduced length of stroke, the result *approximates* to the superior effect of multiple geared engines, as appears by the following tabular summary of the results of the foregoing deductions.

TABLE No. 11.

SUMMARY OF COMPARATIVE NUMBERS, SHEWING THE AVERAGE RELATIVE PERFORMANCES OF THE VESSELS CLASSIFIED ACCORDING TO THEIR LENGTH OF STROKE.

		Average Performance.	
Direct connection engines	3 feet stroke...	95	see Table No. 8.
	2 feet stroke...	160	
Multiple geared engines.	4 feet stroke...	160	see Table No. 10.
	3 feet stroke...	171	
	2 feet stroke...	195	

From which table we observe a gradually improved average performance, denoted by the increasing numbers 95, 160, 171, 195. Whence we remark an indication of the general principle, that in screw propulsion, that arrangement of engine appears most conducive to efficiency, which leads to the adoption of fine pitched screws running at high speed, in preference to coarse pitched screws running at reduced speed.

As regards the *economic* and in some degree the mechanical efficiency of the engines themselves irrespective of the propellers, certain circumstances attendant on the shortness of the stroke, are undoubtedly disadvantageous. Nevertheless, it appears to be conclusively apparent that the engines of screw ships being constructed with ***short strokes***, and therefore capable of making a high number of revolutions per minute, conduces to the attainment of greater advantages in connection with the operation of the screw propeller, than merely compensate for the admitted loss of mechanical efficiency which the engine itself sustains, by reason of the unusual shortness of the stroke as compared with the diameter of the cylinder.

The loss of *mechanical* effect by reason of the unusual shortness of the stroke, chiefly involves certain practical considerations of a nature not usually embraced, or admitted, in theoretical views of the subject; but as to the chemical or economic loss as respects the comparative consumption of fuel, it is apparent that the increased number of revolutions, consequent on the shortness of the stroke, will occasion a certain extra proportional quantity of non-effective steam, which is contained in the steam passages and lost at each stroke; but this admits of calculation, it becomes reduced in proportion as the engines may be worked expansively, and within ordinary limit of practice will not involve considerations materially affecting the general conclusion, that a length of stroke not exceeding *two feet,* may be advantageously applied to SCREW engines up to sixty inches diameter of cylinder, and probably beyond that limit, which result is attended with the important consequence, that it admits of the *sway beam* engine with a *vertical* cylinder being applied within the limit of height, viz. eight feet, to which the machinery of ships of war is usually restricted, as in the following section will be more particularly shewn.

SECTION IX.

THE HEIGHT OF ENGINES FOR SHIPS OF WAR RESTRICTED TO THE HEIGHT OF THE BOILERS.

SWAY-BEAM ENGINES WITH VERTICAL CYLINDERS OF EIGHTY INCHES DIAMETER ARRANGED FOR THE APPLICATION OF MULTIPLYING GEAR, AND HAVING A LENGTH OF STROKE OF TWO FEET, CAN BE CONSTRUCTED WITHIN THE LIMITED HEIGHT OF EIGHT FEET WHICH IS USUALLY ASSIGNED TO THE BOILERS OF SHIPS OF WAR, AND NOT EXCEEDING THE FLOOR SPACE USUALLY OCCUPIED BY HORIZONTAL DIRECT-ACTION ENGINES OF EQUAL POWER.

IT having been shewn, in the previous section, that the limited stroke of *two feet* is apparently preferable to a longer stroke, for the special purpose of driving the *screw propeller,* we now proceed to consider whether this limitation of the engine's stroke renders the *vertical* construction of engines practicable, within the limit of *height* to which marine boilers for ships of war are usually restricted.

Marine boilers of considerable size have on some occasions been made as low as seven feet in height, but practice in boiler construction, and experience of their adaptation for sea service, have shewn that the height of eight feet is much more conducive to a satisfactory result. Boilers of this class, viz., limited to a height of eight feet, (termed "low" boilers,) do not properly admit of having the tubes above the furnaces, when applied to engines of large power, but the tubes are placed beyond the furnaces, and consequently, they inconveniently occupy a considerable space of the ship's floor. The great extent of floor space thus required for the accommodation of the *low* construction of boilers for ships of war, constitutes one of the chief considerations which limits the amount of engine power that can be judiciously applied with due regard to the essential arrangements of the vessel in other respects; but for vessels not essentially ships of war, it may not be required that the boilers be below the water line of the ship, in which case the boilers may be made with the tubes *above the furnaces*, such boilers being about twelve feet in height, termed "high" boilers, and occupying only about half of the *floor space* that is required for the low construction of boiler of equal power.

The same causes that have induced the preference, if not the necessity, of low boilers, not exceeding eight feet in height, for ships of war, evidently rendered it desirable that the *height of the engines* should be restricted to the same limit, and as the height of vertical marine engines of large powers as usually constructed, either on the sway-beam, or on the direct action principle, far surpassed that limit, it occurred to engineers that the *horizontal* construction of engines could be advantageously resorted to, as an alternative well adapted to meet the requirements of the submerged screw propeller; consequently, a great proportion of the largest steam screw ships in the Royal Navy, which require that the machinery be placed below the water line, have been furnished with horizontal engines on the *various plans* of construction which the rival manufacturers have respectively devised and introduced.

The general practice of engineers in the adoption of horizontal plans of construction for screw ship engines in preference to vertical engines, has thus originated in the presumed necessity of the case, and not from any mechanical preference being due to the horizontal engine; but, on the contrary, it is generally admitted that horizontal engines are in many respects practically objectionable, as compared with vertical engines.

In considering the practicability of applying any vertical construction of engine within the limit of height (eight feet only), to which the machinery of ships of war is restricted, the limitation of the length of stroke to *two feet,* by reason of its being favourably applicable, and even preferable to a greater length of stroke for screw engines, is regarded as conclusively determining the question in favour of the *practicability* of adopting vertical engines of the sway-beam principle of construction, though not exactly on the ordinary side lever plan.

It has occurred to the writer, that the admitted advantages of the side lever or sway-beam *principle* may be preserved, its construction be greatly simplified, and certain objections which have been urged against it, in consequence of several parts being subjected to *cross strains,* be in great measure obviated, by adopting the device of placing a CENTRAL SWAY-BEAM immediately above the condenser, and by keeping the sway-beam within the restricted limit of height, by means of a TRUNKED PISTON, through which trunk or hollow piston rod, the end of the sway beam may be connected directly with the piston. By this *modification* of the side lever engine, the approved working principle of the sway beam is retained, the engine becomes simplified by avoiding many of the parts subject to *cross strain;* the arrangement is convenient for the application of *multiple gearing,* and engines of eighty-inch cylinders can be constructed within the limited height of *eight feet* from the top of the keelson. This plan of engine, therefore, embraces those essentials of construction which appear, by the foregoing investigations, to be conducive to the effective performance of screw ships.

The engines of 25 horse power, which the author has constructed for the purpose of exhibition, and for testing the working efficiency of the proposed arrangement, will shew practically the general *principle* of construction; but it is to be observed, that the details of the design have not been fully matured with the care and attention purposed to be bestowed upon them, should the principle be approved and adopted as the base of a *classified* system. Further, for the information of those who may not have the opportunity of inspecting the engines, the following description, with the annexed diagrams, will point out the particulars in which the proposed arrangement differs from that of the ordinary side-lever construction.

DESCRIPTION.

This arrangement of engine has been designed with a view to *simplify* the construction of the side lever, or sway-beam principle, and to make the same engine available either for screw ships or for paddle-wheel vessels.

By referring to the annexed diagrams, (Nos. 1 & 2,) it will be observed, that as compared with the ordinary construction of the side lever engine, the plan now proposed has the following advantages:—

1st. The engine occupies less width, by a CENTRAL SWAY-BEAM being placed *above* the condenser instead of *two side levers* one at each side of the cylinder; and the height of the engine does not exceed the usual limit in proportion to the length of stroke, by reason of the piston connecting rod vibrating within a HOLLOW TRUNK *connected directly with the piston,* whereby the sway-beam does not work above the usual height of the cylinder cross head.

2nd. The sway-beam being in a central position, and connected *directly* with the piston and with the crank, the engine is *not so liable to breakage* as the ordinary side lever engine, and the probable extent of damage consequent on any part giving way is greatly reduced.

3rd. The cross head, cross tail, air pump cross head, cylinder side rods, and parallel motion gear, are by the proposed construction *entirely superseded.*

4th. In consequence of so many parts of the ordinary side lever engine being thus done away with, all parts of the proposed engine are *more accessible and more easily attended to when in operation.*

5th. By means of the TWO AIR PUMPS, one on each side of the main centre, the engine is nearly balanced, and, therefore, capable of being worked at very reduced power, and less liable than marine engines generally to be *"brought up"* in a heavy sea.

In the detail of these engines, all parts are constructed with a view to *obviate the usual causes of breakage;* for instance, the piston is made *without any junk ring,* and therefore not requiring the bolts, nuts, and keeps, usually connected therewith, any one of which by becoming loose, as frequently happens, may occasion the breaking down of the engine. The steam slides are so proportioned and adjusted as not to close the exhausting port till *after* the turn of the stroke, thereby in a great measure obviating the danger of breakage by water being confined in the cylinder, and superseding the escape valves: these material advantages are gained at a trifling sacrifice of steam. The slides, also, are arranged for being worked both ahead and astern by one fixed eccentric, instead of two, as usual. THE EXPANSION GEAR is on a plan that operates with precision, *at whatever speed the engine may be driven*, and affords a means of recording the expansive working of the engine, thereby perfecting the means of *self-registration* by which the management of the engines may be effectually tested and checked. The feed pumps and brine pumps are connected and worked by an adjustment lever, whereby the *feed* supplied to the boiler, and the *brine* extracted from it, may be always *in proportion to the steam used*, as regulated by the expansive valve.

DIAGRAM, No. 1, shews the proposed principle of construction adapted to *screw ships*. By this diagram it appears that engines of *sixty inches* diameter and two feet stroke, which limited length of stroke has been found to be favourably applicable to the screw propeller, can be constructed within the limit of height necessary for the lowest marine boiler, viz. eight feet; and the plan affords facilities for the application of *multiplying gear*, which in screw propulsion has been found conducive to the most effective results.

This arrangement is well adapted for screw ships of war, which require that the machinery be as low as possible below the water line, the bottom of the sole plate being provided with a *recess*, whereby, when the engines are placed *across* the ship, the keelson timber may pass between the air pumps, and the bottom of the sole plate be bedded down upon the ship's floor.

DIAGRAM, No. 2, shews *the same engine,* adapted to *paddle wheel vessels,* by leading the connecting rod *up* to the paddle wheel shaft, instead of *down* to the screw propeller shaft; in this case each engine may have two cylinders, as shewn by the Diagram, No. 2, viz., one at each end of the sway beam, the paddle wheel shaft being placed above one of the cylinders, as usual with direct action engines; or the paddle wheel may, if required, be placed on a second motion shaft, which will afford facilities for the application of differential gearing, whereby the vessel may be rendered very effective for "TOWING."

As regards the floor space that will be occupied by these engines, by adopting the low plan of construction represented by Diagram No. 1, which is adapted for driving the submerged screw propeller, a pair of sixty-inch cylinder engines will occupy the space of 20 ft. by 16 ft., which does not exceed the floor space usually occupied by horizontal engines of equal power: and on the plan of construction shewn by diagram No. 2, (adapted for paddle wheel vessels) there will be *four cylinders* of sixty-inches diameter erected upon the same amount of floor space. These double cylinder engines by being placed *across* the ship, as in DIAGRAM, No. 1, will be applicable to screw propulsion. In this case the driving wheel will be six feet higher than in Diagram, No. 1, but the engine power will be doubled without any increase of the floor space occupied by the engines.

SECTION X.

THE TERM "HORSE POWER" CONSIDERED.—ORIGIN OF THE TERM "NOMINAL HORSE POWER."

ADOPTED RULE FOR CALCULATING *"NOMINAL HORSE POWER"* APPLICABLE TO THE CIRCUMSTANCES UNDER WHICH STEAM ENGINES WERE ORIGINALLY CONSTRUCTED, BUT NOT APPLICABLE, AS A MEASURE OF POWER, TO THE PRESENT PRACTICE OF MARINE ENGINE CONSTRUCTION.

ANOMALOUS CONDITION OF MARINE ENGINE AFFAIRS CONSEQUENT ON THE "NOMINAL HORSE POWER" BEING STILL REFERRED TO AS A MEASURE OF POWER.

THE FORCE BROUGHT INTO ACTION BY THE PISTON OF AN ENGINE, CAPABLE OF BEING ACCURATELY ASCERTAINED BY MEANS OF THE INSTRUMENT CALLED THE "INDICATOR," WHENCE THE *"INDICATED HORSE POWER"* MAY BE DEDUCED.

THE "INDICATED HORSE POWER," ADOPTED AS THE MEASURE OF POWER, ON WHICH THE CLASSIFICATION OF ENGINES AND BOILERS IS PROPOSED TO BE BASED.

PREPARATORY to determining on a SYSTEM of *classified engines,* and arranging them in a *gradation of sizes* suitable for meeting the requirements of commercial and national steam ship service in regard to power, it becomes necessary that, in the first place, we explain the sense in which the term "HORSE POWER" is to be used, and determine the measure of mechanical force which is implied by that term.

In the original introduction and application of the steam engine to pumping water from mines, and other mechanical purposes usually performed by horses, it was necessary to devise a conventional measure of power, in order to convey a definite apprehension of the amount of working effect that an engine, when put into operation, would produce; and, probably, no better method of giving a comprehensive and popular idea of the work that an engine was calculated to perform, could *originally* have been devised, than by comparison with the number of working horses that would be required to be simultaneously employed to do the same amount of work; and, inasmuch as at that time the mechanical conditions under which steam engines were constructed and put to work by the original patentees were approximately determinate and invariable, the conventional rule that was adopted for calculating the mechanical effect of an engine of specified dimensions, and of expressing it by the term "*nominal horse power,*" was sufficiently well defined to give a closely approximate, and well understood measure of the effective force which an engine would actually produce; or to deduce the required dimensions of engine necessary for producing any given effect.

After a few years, however, steam engines were constructed and put into operation under a *variety* of conditions; for example, there were *single stroke* atmospheric engines, *double stroke* low pressure condensing engines, *high pressure* non-condensing engines, and engines using the steam on the *expansive* principle in every grade of variation.

Under these altered circumstances, the conventional rule for calculating the nominal horse power of steam engines, was no longer generally applicable for determining the amount of *effective power* that an engine could be made actually to produce; but, nevertheless, the term continued to be used, and is still adopted as the *base* on which steam engine contracts are generally founded, in respect to the *size* of engine intended to be contracted for.

By the established practice of trade, the term "nominal horse power," still determines, with a tolerable degree of precision, the *dimensions* of the ENGINE itself,—that is, the dimensions of the *cylinder* according as it may be constructed on one or other of the principles above referred to; but the dimensions of a very important part of steam machinery, viz., the BOILER, not having been specifically defined and embraced in the recognized rule for calculating the horse power, are still undetermined with reference to the dimensions of the engines; and, although the dimensions and construction of the boiler constitute the elementary *means* of producing the power, and limit the amount that will actually be realised, (which power is, in fact, *created* by the boiler, and merely *developed* by the agency of the engine,) nevertheless, the practice of marine engine manufacturers, in regard to boiler *dimensions* and construction with reference to *horse power*, has been subject to no fixed regulation, and not only is the practice of the general trade indeterminate, but the practice even of the same makers in regard to boiler proportion with reference to power, *varies considerably,* though the price per horse power at which engines and boilers are contracted for by the principal manufacturers is nearly the same in all cases.

Seeing, therefore, as above stated, that the term "*horse power,*" though still defining the *dimensions* of the engine, does not define the dimensions of the boiler, and assigns no specific limit whatever to its actual *working power,* beyond what the discretion of the manufacturer may dictate, and that the practice of the trade does not even profess to recognize any *determinate scale of dimensions* in regard to the reputed horse power of boilers, but varies even as much as 30 per cent., it certainly does appear to be singularly unaccountable, that in the estimation not only of the public generally, but in the imagination of proprietors deeply concerned in steam ship construction, the term "*nominal horse power*" should be still acknowledged, not merely as the measure of the money to be paid for an engine, (as, for instance, £50 per horse power,) but be regarded as an equally definite measure of the *amount of work* that the engine will actually produce,—the evils of this system are also such as *impede improvement,* for the irregularities of practice in connection with boiler proportions, have induced arbitrary proceedings in connection with marine engine construction and adjustment, which defeat the establishment of satisfactory *checks on engine management afloat,* and render the term "nominal horse power" altogether *delusive* and unfit for being made the base of comparing one engine with another, either as regards working efficiency or contract price.

In marine engine CONTRACTS, moreover, the rate of expenditure of fuel, with reference to the work actually performed, is but seldom made the subject of *specific stipulation;* and even in mercantile practice, where the rate of fuel expenditure is presumed to be kept, it generally has reference to the *delusive* "nominal horse power" of the engine, and consequently, the most viciously constructed boiler, inferior fuel, and bad stoking, may all pass current for good, if only the working management of the engine be judiciously and skilfully conducted; in no other description of practical operation is there such scope for *manœuvre* as in marine engine construction and management, with reference to the "*duty*" performed by engines of given "nominal horse power."

The paradoxical nature of the term "nominal horse power," may be somewhat illustrated by observing that its application to steam engines is somewhat analogous to the term "*tonnage,*" as heretofore applied to shipping; in ship building, the term "tonnage" recognized, till recently, only the dimensions of *length* and *breadth,* and on these dimensions alone the calculation of tonnage and the contract price of the ship was nominally based; but, as is well known, in consequence of the *depth of hold* not having been specifically embraced, the mere term "tonnage" did not even approximately define the tons weight, or bulk, that a ship could be built to carry. MERCHANTS, however, in regard to ships, always understood the limited application of the term "tonnage," and did not solely rely on that term as fully expressing their views and objects in respect of the ship's *build;* it was invariably understood between the proprietors and their ship builder, what were the desired properties of the vessel, as regards its *capacity* for freight, adaptation for *speed*, and other important qualities.

STEAM SHIP PROPRIETORS, on the other hand, appear to have been altogether *mystified* by the steam engine, and, though equally interested in the contract horse power *price* of a steam engine, as well as in the amount of *effective power* that the engine will exert with a given expenditure of fuel, they have, it may be said, invariably omitted all stipulations on the latter point; it rarely happens that the term "DUTY," (which term embraces the combined properties both of engine and boiler, as shewn by the *work* performed and the *fuel* consumed,) has constituted any specifically defined condition of a marine engine contract. So generally has this been the case, that the writer, in the whole course of his twenty years' experience as an engine *manufacturer* and engineer in charge of steam ship construction, has never known the rate of "*duty*" to be performed by a *marine* engine, expressly stipulated for and made a condition of the engine contract, though such condition, in regard to "working duty," is quite usual for engines applied to *mining* and other manfacturing purposes, and has been attended with *incalculable benefit* to the interests concerned; and, in fact, it has constituted the base on which mining *prosperity* has been for many years in a great measure dependent.

Doubtless it is not to be expected that *marine* engines should attain to the working economy of mine *pumping* engines, but it may be usefully remarked that a comparison of the two systems will be found to present an amount of discrepancy, leaving no doubt that there is room for great economic improvement in marine engine constructive practice and management; and when the difference of *cost* of the fuel used in the two cases comes to be duly considered, it cannot be questioned that steam ship PROPRIETORS will discover a strong incentive to reduce the wide marginal difference of expense that presents itself, between *mining* and *marine* engine economy; the requisite arrangements for effecting the object of recording the "DUTY" performed by marine engines working on the expansive principle is essential to this, and it constitutes one of the objects which the proposed *classified construction* is intended to establish.

In the discussion of matters affecting steam ship construction, it has been quite usual for the relative proportion of the "*nominal horse power*" of the engine, and the *tonnage* of the ship, (notwithstanding the indefinite meaning of both these terms,) to be referred to as approximately indicating the proportion between the *amount of force* to be employed, and the *bulk* to be transported; and these comparisons are adopted, not merely with reference to a particular steamer that may be in question, but as a general base of comparison one ship with another,—so much so, that the presumed necessity of the nominal horse power being definitely proportional to the ship's tonnage, in order to produce a required steam ship performance, has been referred to, as constituting an obstacle to the Author's views on the classification of engines, within any moderate limit as to the *number* of engines that would be necessary to meet the great variety of sizes to which steamers are built, and presumed to require a proportional variation in the *size* of the engines to be adopted. This odjection being held to be erroneous, the elucidation of its fallacy becomes indispensable to the object of this treatise; it is, therefore, purposed, in the following section, to shew *the great extent of variation of powers,* that a steam engine of *definite size,* and worked under the ordinary conditions of modern practice, is capable of embracing,—observing that, in these investigations, the use of the term "nominal horse power," and of the system of calculation on which it is based, will be *discarded,* and that, in speaking of engine power, its gross amount, as actually exerted by the piston, and as ascertained with the aid of the "INDICATOR" by a well known and admitted process of calculation, will be the recognized measure of power herein referred to; the power thus ascertained by actual admeasurement being denominated the "*indicated horse power.*"

SECTION XI.

THE LIMITED NUMBER OF EIGHT ENGINES ARRANGED ON THE GRADATION OF SIZES, DENOTED BY TEN, TWENTY, THIRTY, FORTY, FIFTY, SIXTY, SEVENTY, AND EIGHTY INCHES DIAMETER OF CYLINDER, AND CONSTRUCTED WITH A VIEW TO THE COMPLETE ADOPTION OF THE EXPANSIVE PRINCIPLE, WILL AFFORD ALL THE VARIETIES OF POWER, NOW COMMONLY IN USE, AND MEET THE PROBABLE FUTURE REQUIREMENTS OF STEAM SHIP SERVICE, BOTH COMMERCIAL AND NATIONAL.

In the arrangement of a specific system of classification, although the adaptation of the engines is required to embrace both the paddle wheel and the screw systems of propulsion, it will be convenient to prosecute the enquiry with reference to one or the other system only, and for the reasons stated in Section VI., we will in the first place adapt our system to the SCREW PROPELLER as indicated by Diagram No. 1, shewing subsequently its application to the PADDLE WHEEL, agreeably to Diagram No. 2.

The screw propeller, though now in very general use for commercial purposes, is chiefly employed in connection with auxiliary power, but the greatest fleet of screw steamers under one direction, is that of the Royal Navy, and any system of classified engines which will embrace the whole range of power employed in the screw ships of the Royal Navy, may be expected to fully meet the requirements of the merchant service.

By the published records of screw ship trials, before referred to, it appears that the *screw engines* of the Royal Navy vary in size from 30 up to 1500 "*indicated horse power;*" these therefore are the present limits which our system of classified engines is required to embrace.

We have already seen by the foregoing Section, No. VIII., that two feet is a favourable length of stroke for screw engines; assuming, therefore, that the classified system of engines be all of *two feet stroke*, and that the adaptation of the screw admit of the engine working at sixty strokes per minute, and assuming the regulation pressure of the steam at ten lbs. per square inch, and the average vacuum on the cylinder to be twelve lbs. per square inch, the following Table represents the calculated range of "*indicated horse power,*" that engines of *ten, twenty, thirty, forty, fifty, sixty, seventy*, and *eighty*, inches diameter of cylinder will exert, according as the engines may be worked more or less on the expansive principle by means of expansion gear, which is always under the control of the engineer, presuming of course that the engines be well proportioned and constructed on principles known to be conducive to working efficiency, and of materials and workmanship such as any well regulated establishment in Great Britain will not fail to produce.

TABLE No. 12.

SHEWING THE PROPOSED SIZES OF CLASSIFIED ENGINES.

Classification Number of the respective Pairs of Engines.	Diameter of Cylinder.	Range of "*Indicated Horse Power*" for which the Engines are respectively applicable according as they may be worked more or less expansively.
	Inches.	Indicated Power.
No. 1	10	8 Horse Power to 25 Horse Power.
2	20	30 ,, ,, 100 ,, ,,
3	30	70 ,, ,, 200 ,, ,,
4	40	130 ,, ,, 400 ,, ,,
5	50	200 ,, ,, 600 ,, ,,
6	60	300 ,, ,, 900 ,, ,,
7	70	400 ,, ,, 1200 ,, ,,
8	80	500 ,, ,, 1500 ,, ,,

If engine power be required beyond the amount of 1500 indicated horse power, it may be advisable to apply *four* cylinders, rather than two cylinders, of greater size than eighty inches diameter, several large screw ships in the Royal Navy are thus fitted with four cylinders; and the proposed plan of classified engine construction admits of two pairs of engines being placed side by side, and connected with the same shaft, consequently two pairs of engines, No. 7, will be availably applicable, and they will collectively work up to 1200 × 2 = 2400 indicated horse power, and two pairs of No. 8 will work up to 1500 × 2 = 3000 horse power, which exceeds the greatest amount of power now applied to screw propulsion.

Thus it appears that a classification of the above eight sizes of engines would, as regards power, fulfil all the requirements of screw ship service up to 1500 indicated horse power, and that above the limit of

1500 horse power, two pairs of the classified engines may be connected with the screw propeller shaft, to produce any greater amount of power that may be required up to 3000 horse power.

The foregoing Table, No. 12, has been calculated on the supposition of the supply of steam not being checked by means of the throttle valve, and that the *speed* of the engine is not reduced below sixty strokes per minute, but both these additional means of reducing the working power are constantly available; and experience shews that with *well balanced* sway beam engines, there is no difficulty whatever in working an engine down to *one-fifth* of its *maximum* power; hence, the available limit of power of the respective classified engines will be more completely shewn by the following table:—

TABLE No. 13.

SHEWING THE MINIMUM AND MAXIMUM INDICATED POWERS OF THE EIGHT SIZES OF CLASSIFIED ENGINES.

Classified Number.	Number and size of the cylinder.		Limits of available variation of power, expressed in "indicated horse power."			
		Inches.				
No. 1	2 cylinders of	10	5 h. p.	to	25	h. p.
2	2 ,,	20	20 ,,	to	100	,,
3	2 ,,	30	40 ,,	to	200	,,
4	2 ,,	40	80 ,,	to	400	,,
5	2 ,,	50	120 ,,	to	600	,,
6	2 ,,	60	180 ,,	to	900	,,
7	2 ..	70	240 ,,	to	1200	,,
8	2 ,,	80	300 ,,	to	1500	,,
2 pairs No. 7	4 ,,	70	480 ,,	to	2400	,,
2 8	4 ,,	80	600 ,,	to	3000	,,

It will be observed, by inspecting the foregoing table, (No. 13,) that nearly all the varietieso f required power are embraced by *more than one* engine of the classified system; for example:—

TABLE No. 14.

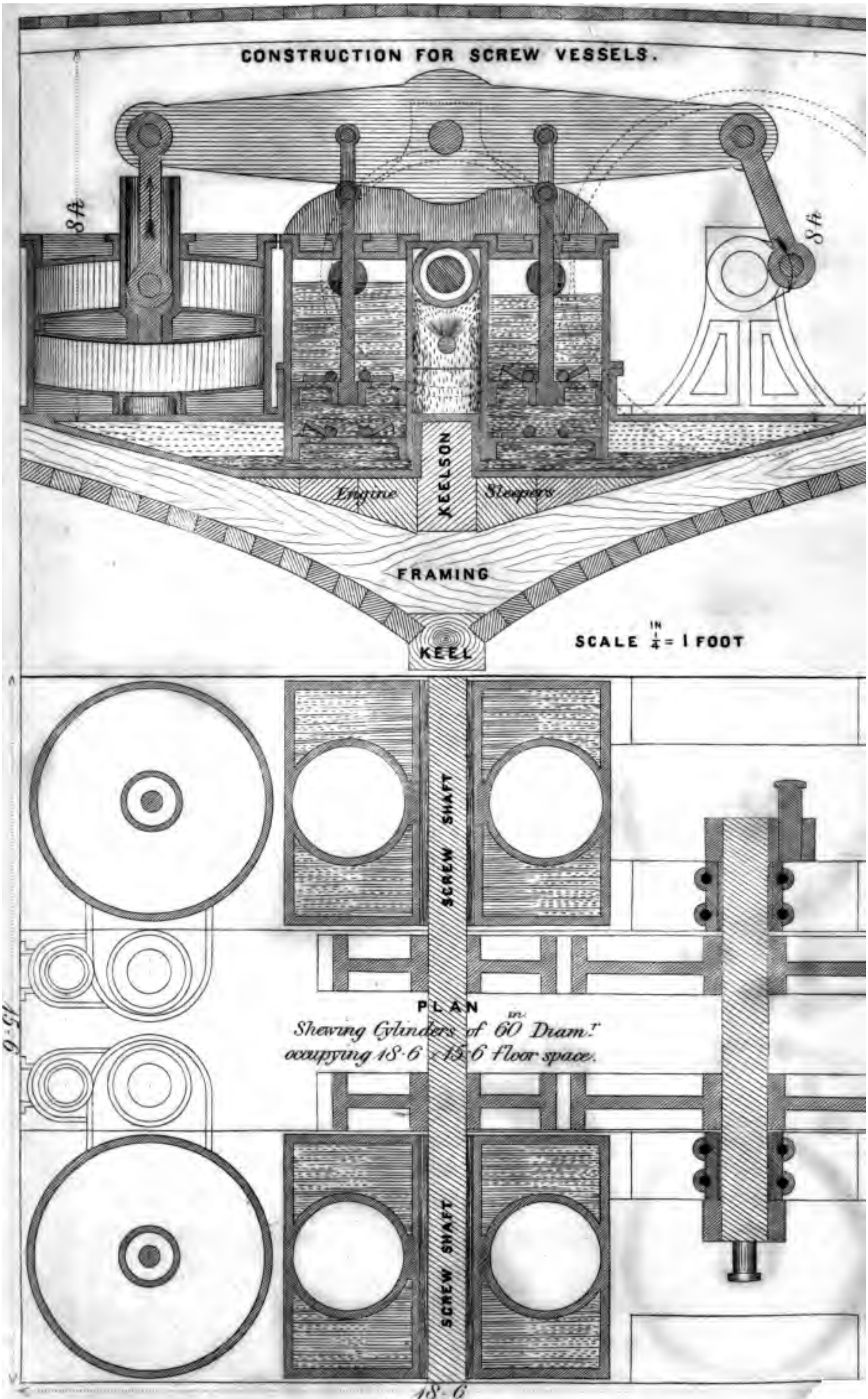
SHEWING THE *CHOICE* OF CLASSIFIED ENGINES AVAILABLE FOR ANY GIVEN AMOUNT OF POWER.

25 H. P.	is within the working limits of No.	1 or 2.
50	„ „ „	2 or 3.
100	„ „ „	2 or 3 or 4.
250	„ „ „	4 or 5 or 6.
500	„ „ „	5 or 6 or 7.
750	„ „ „	6 or 7 or 8.
1000	„ „ „	7 or 8.

thereby affording for the whole range of power in ordinary use not one engine only but a *choice* of available engines; and the selection of the smaller, or the larger size, in any particular case, may be governed by circumstances,—such as the difference of *cost,* and whether the object, or trade, for which the ship may be intended, renders mercantile cargo at *moderate speed,* or express service at *high speed,* of the greater importance.

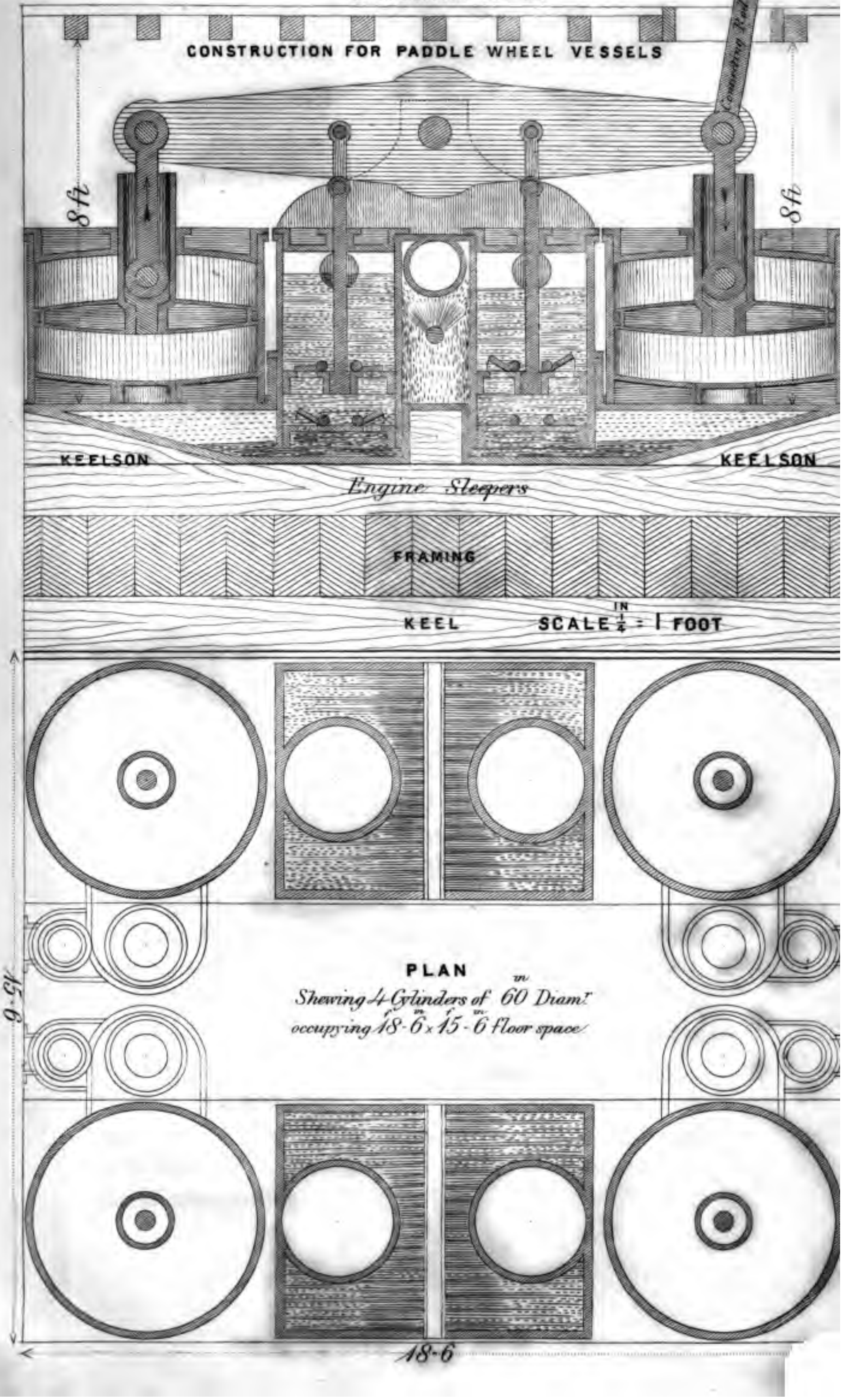
The foregoing adaptation of power has reference especially to screw ships requiring that the engines be on the low plan of construction, represented by Diagram No. 1,—but if we be not restricted to this condition, the arrangement represented by Diagram No. 2, becomes available, and our range of power, with reference to the floor space occupied by the engines, will be doubled, which arrangement occupying

DIAGRAM Nº I.


CONSTRUCTION FOR SCREW VESSELS.
8 ft
8 ft
Engine
KEELSON
Sleepers
FRAMING
KEEL
SCALE 1/4 IN = 1 FOOT
SCREW SHAFT
SCREW SHAFT
PLAN
Shewing Cylinders of 60 in Diamr
occupying 18·6 × 15·6 floor space.
15·6
18·6

J Clarke Sc Devonport

DIAGRAM Nº 2.


CONSTRUCTION FOR PADDLE WHEEL VESSELS
Connecting Rod
8 ft
8 ft
KEELSON
KEELSON
Engine Sleepers
FRAMING
KEEL
SCALE ¼ IN = 1 FOOT
PLAN
Shewing 4 Cylinders of 60 in Diamr
occupying 18 f-6 in x 15 f-6 in floor space
15-6
18-6

but little floor space in the ship, is peculiarly adapted for vessels of great engine power.

TABLE No. 15.

SHEWING THE POWERS OF THE CLASSIFIED ENGINES, WHEN FITTED WITH DOUBLE CYLINDERS AS REPRESENTED BY DIAGRAM No. 2.

Classification Number.	Number and size of the cylinders employed	Available amount of *indicated* horse power.
1	4 cylinders of 10	10 h. p. to 50 h. p.
2	4 „ „ 20	40 „ to 200 „
3	4 „ „ 30	80 „ to 400 „
4	4 „ „ 40	160 „ to 800 „
5	4 „ „ 50	240 „ to 1200 „
6	4 „ „ 60	360 „ to 1800 „
7	4 „ „ 70	480 „ to 2400 „
8	4 „ „ 80	600 „ to 3000 „

It will be observed that the engines represented by Diagram No. 2, are adapted for being connected with the paddle wheel shaft by being fixed *longitudinally* in the vessel, but if connected with a screw propeller shaft, their position in the ship would be *transverse,* as shewn by Diagram No. 1. It will further be observed, that the engines with four cylinders, of No. 6 size, arranged as represented by Diagram No. 2, amounting to 1800 indicated horse power, would occupy a space in the ship's floor of 18ft. 6in. by 15ft. 6in., being an amount of power in proportion to the floor space occupied by the engines which is believed not to have been surpassed by any of the various arrangements that have been introduced even on the direct action principle of construction.

Hence it appears that a classified system of 8 engines only, viz., of 10, 20, 30, 40, 50, 60, 70, & 80 inches diameter of cylinder, and all of the same length of stroke, viz., two feet, would meet all steam ship requirements, both in the merchant service and in the Royal Navy, which services employ, at the present time, not less than one thousand engines of different sizes and constructions, with every probability of the diversity of sizes being still further indefinitely increased, unless the practice of such unrestricted engineering be checked by the DIRECTORS of steam fleets being convinced and availing themselves of the benefits that would result from the introduction of some well-matured SYSTEM of marine engine CLASSIFICATION.

By the foregoing remarks, the writer hopes that, in some measure, he may have elucidated the nature of the doubts and difficulties with which steam marine engineering is commonly embarrassed, and in consequence of which, the subject of steam engine construction is generally regarded as a mystery, which ordinary intelligence dreads to penetrate, but which, when dispelled, and the *principles* of the subject become practically understood, the MARINE STEAM ENGINE at once appears more remarkable in respect to the unappreciated *simplicity* of the constructive principles on which its action is dependant, than in respect to any other of its inestimable attributes.

SECTION XII.

CLASSIFICATION CONSIDERED WITH REFERENCE TO ITS IMMEDIATE OPERATION ON STEAM SHIP CONSTRUCTION AND EFFECT ON STEAM FLEET ECONOMY OF MANAGEMENT.

THE general effect of adopting the principle of classification, having been referred to as leading to an improved system of *discipline* and effective *co-operation* in steam FLEETS, it is purposed that we now bring more particularly under consideration its beneficial tendency in connection with the *mercantile economy* of steam FLEET MANAGEMENT.

1st. BY CLASSIFICATION, the arrangement of the engine department on board all the different vessels collectively constituting a mercantile or a national steam FLEET, would be *similar* throughout,—all the cocks, gauges, and other appliances, too numerous to particularize, but essentiailly connected with the safe working and proper operation of the engines, would be similarly located; the *starting gear* would be similarly constructed, and the same process of practical manipulation and management would be pursued in connection with the engine department of *each ship* of the whole FLEET; consequently, the engineers, stokers, and other hands employed on board one ship, would be familiar with the machinery of all other vessels, and be *competent* to co-operate in the engine department of any ship that might require such assistance; there would be no peculiarities of treatment which now attach to engines of different constructions, and which, with fresh hands on board, are *frequently* the cause of mismanagement and of the engines not being promptly under command, whereby *accidents* when on service, and particularly when in port and in crowded channels, frequently ensue.

2nd. BY CLASSIFICATION, the *attention* and *skill* with which the engine department of different ships respectively may be conducted, would be ascertained by the test of *comparison*,—for if the general arrangements be alike in all vessels of the fleet, similar circumstances of management would produce approximately corresponding results,—habitual inattention, or want of skill would soon be detected by comparing the casualties, general effectiveness, and working expenses of one shiy with another, or by occasionally changing the hands in charge of any particular ship; but in the absence of such comparative checks, the greatest abuses may pass undetected, or be *plausibly* accounted for, and the numerous class of accidents which result from negligence and incompetency can be seldom traced to their originating *cause*, and be conclusively brought home to the parties *really in fault*.

3rd. BY CLASSIFICATION, the engines would be of assured proportions and efficiency in all parts, new ships would no longer be experimental in the engine department, and subject to the *numerous chances* of derangement both as regards *misunderstood* management and mechanical *defect*, which must always be expected to attend the successive introduction of *new plans*, and thus the chances of failure on service would be greatly reduced.

4th. By classification, certain Foreign Ports could be supplied with means for meeting all probable and unavoidable wear and tear incidental to the adopted system, whereby the occurrence of accident or defect on foreign service would be met, and the means of effecting necessary renewals be more promptly provided.

5th. By classification, all the *weights* connected with the engine department would be precisely known, and thus a serious source of error to which steam ship construction has hitherto been liable, and which affect not merely the displacement of the ship, but also the stability and various other properties of the greatest importance, would, as regards the *weight* of the engines, boilers, and machinery, and the *space* occupied by them, be altogether obviated,—responsibility for the occurrence of steam ship failure would then more distinctly attach to one or other of the constructive departments in charge, and the chances of miscalculation or mal-arrangement would be greatly reduced.

6th. By classification, the properties of each class of engines would be accurately known, and consequently the merits or faults of the ship's build, as regards its *adaptation for steam propulsion* could be approximately ascertained, the relative performance of *different ships* of different build could thus be more satisfactorily *compared* and the science of steam ship construction would thereby be promoted, much more effectually than is possible, so long as ships of *unprecedented model* are propelled by engines of *novel design*, from which unregulated system it results that superior merit in construction may be erroneously attributed to inadequate causes, and that in case of failure from malconstruction, the ship builder and engineer, mutually attributing the fault to each other, as occasionally happens, the cause of failure remains unproved or becomes mystified, the error may again recur, and the interests concerned be again sacrificed.

7th. By classification, the engines to be contracted for, would be *specifically* determined, and the work of engine manufacture being thus limited to the execution of the specified plan, would then be of a nature that admits of being thrown open to a far wider field of *competition* than at present, the tenders would all have reference to the *same work*, whereby the rivalry of manufacturers would be beneficially promoted, and the cost of engines would be determined on the approved principle of manufacturing competition, for contract work duly defined and specified.

8th. By classification, the engines for steam fleets could be provided in anticipation of emergency without reference to particular ships, and the permanent upholding of the *engine stock*, both afloat and ashore, would be facilitated and economised, for independently of the reduced liability to accidents before referred to, the accidents that might occur would be more readily corrected, the perfect parts of disabled engines could be again appropriated in the reconstruction of engines, or be kept in store ready for the first ship that might require them.

9th. By engine classification being made applicable to ships of war, further progress would be made in a direction already sanctioned by approved experience, for the *principle* of classification has already been conceded in the National Service, and for many years partially acted upon, as applicable to a great variety of warlike equipment; for instance, the analogous classification of masts and yards has been adopted with now *acknowledged benefit,* notwithstanding the doubts and delays with which the original proposal was entertained, and there are several *thousands* of articles of naval stores, all contracted for under public competition, to be made in exact conformity with the *regulation patterns;* excepting, however, STEAM ENGINES! the most important item of naval equipment now in requisition, which has been already adopted in the Royal Navy as the propelling power of nearly two hundred vessels, and promises to be still further of greatly extended service, by being ere long employed either as an *auxiliary,* or as the *principal* MOVING POWER on board of every ship, both in the mercantile and national service of GREAT BRITAIN.

THE AUTHOR having thus endeavoured to express the views which he entertains on STEAM SHIPPING INTERESTS, and to explain the principles and develope the practice of the procedure which he conceives would be conducive to NATIONAL PROGRESS, he must now leave the subject to make its own impression on public opinion by the force which may attach to its own INTRINSIC IMPORTANCE.

IN conclusion, the Author begs to observe, that the foregoing Treatise has been confined exclusively to the elucidation of the PRINCIPLES on which he conceives that Marine Engine *Classification* is dependant, both as regards his exposition of the SYSTEM hitherto pursued, by which all approach to classification has been virtually overruled,—and also as respects the course of investigation by which future advantage may be taken of the experience which the great variety of dissimilarly constructed Steam Vessels now in operation have afforded. The practical prosecution of the subject will require that the *constructive details* of the proposed classified system of Marine Engines be minutely determined. In this most interesting labour the Author has already made some progress; but he defers the prosecution of the matter until the reception of his present effort shall have determined the propriety of further publication.

APPENDIX;

DESCRIBING

The Theoretical Principle and the Practical Construction of Atherton's Patent Eccentric Expansion Apparatus.

APPENDIX.

Note.—As Mr. Atherton's duties in H.M.S. do not admit of his giving attention to general business as an Engineer, he has appointed Mr. Alexander Gordon, Engineer, 22, Fludyer Street, Whitehall, London, as his principal Agent for the prosecution of his Patent Expansion Gear, to whom he begs to refer all persons who may be disposed to entertain the subject of the Invention.

In publishing, for the notice of the mercantile interests, the system of Expansion Gear which Mr. Atherton has invented, and placed at the disposal of the Lords Commissioners of the Admiralty, for the use of the Royal Navy, he begs to submit the following particulars, in illustration of the defects of the *Cam-motion* Expansion Gear usually adopted in steamers; and also to describe his recently improved *Eccentric* Expansion Gear, by which the defects of the Cam-motion Expansion Gear are obviated.

The advantages in point of economy of fuel, of working steam expansively, being admitted, the mode of effecting that object is a matter which deeply affects the interests of Steam-engine Proprietors; particularly the interests of Steam Shipping Companies; and more especially the Owners of Screw Vessels, of which the engines are worked at a rate of speed for which the Cam-motion Expansion Gear is not satisfactorily applicable.

In marine engines, the expansion of steam may be partially effected by the steam slide alone; but when the steam slide *only* is used, the steam is not usually *cut off* at less than two-thirds of the stroke; and to obtain the remaining small degree of expansive action, through about one-third of the stroke only, the danger of breaking down the engine is incurred by the liability of water being confined in the cylinder, or else the steam does not act with its full force on the piston, by reason of the steam-ports not being fully opened; and in all cases, the very limited extent to which steam is worked expansively by means of the steam slide alone, is far short of the limit to which the principle of expansion may be advantageously carried out; consequently, an additional expansion slide is employed which is generally driven by the apparatus known as the *Cam-Motion*, by the operation of which the expansion slide receives a *sudden motion* or or impulse, by which the steam way is opened, and again another sudden impulse in the opposite direction, by which the steam-way is closed; so that, in *each* revolution of the engine, the steam-way having to be opened twice and closed twice, *four* such impulses or sudden motions, *in alternately opposite directions*, require to be communicated to the expansion slide. It follows, therefore, that in marine engines making, for example, 20 revolutions per minute, the expansion slide and all the apparatus connected therewith, has to be started into motion, and as suddenly arrested, 80 times per minute; and in the case of direct-action engines making *seventy five revolutions per minute*, as is frequently required of engines even of large size driving the screw-propeller, the number of such distinct movements to be communicated by the Cam-Motion to the expansion slide, *amounts to* 300 *per minute:* and, further, supposing the steam to be taken on at the turn of the stroke, and to be cut off at one-eighth of the stroke, the expansion slide will require to be started into motion, arrested, and again started upon its back motion all in the period of about *one-tenth of a second.*

Such being the required action of the Cam-Motion Expansion Gear, the apparatus soon becomes defective, and does not operate with precision; consequently, the *economy* which ought to be derived from the principle of working expansively fails of being realized.

To obviate the defects above referred to, it is proposed to drive the expansion slide by means of an ECCENTRIC MOTION, as represented by the drawings annexed. It will be observed that the expansion slide, being driven by an eccentric wheel, *is not subject to any sudden impulse*, but is kept in continuous motion like the steam slide; it will consequently operate as *noiselessly* as the steam slide, be as little liable to derangement, and work with the same *invariable precision*, whatever be the number of revolutions at which the engine may be driven.

THEORETICAL PRINCIPLE.

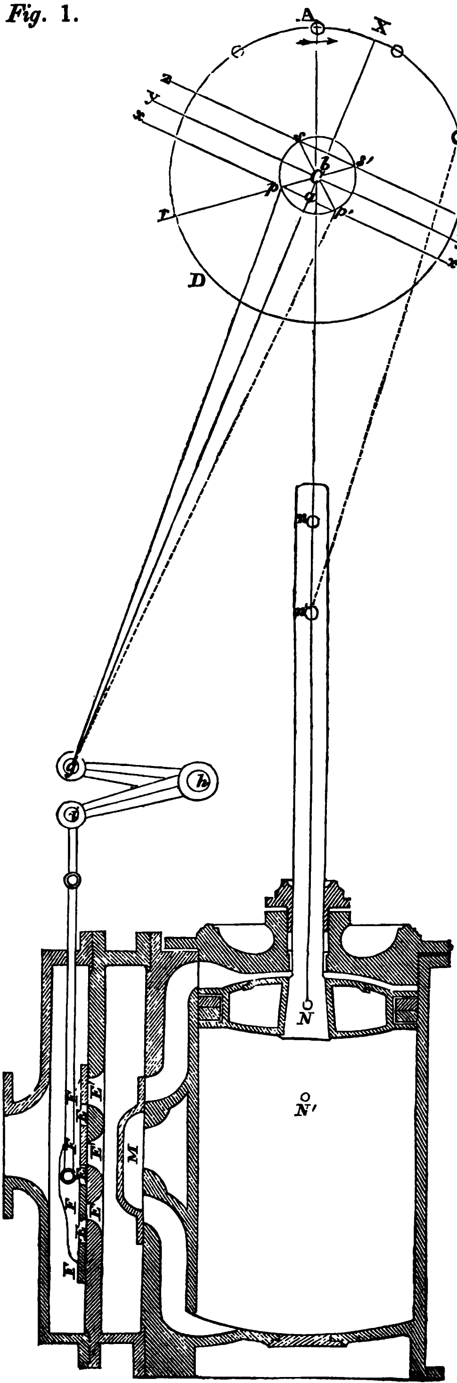
Referring to Fig. 1—the Engine is supposed to be taking on the steam at the extremity of the stroke; F F is the expansion slide, drawn in this case similar to the common grid-iron slide, with three apertures; E E E are the three apertures through the slide F F; E' E' E' are three corresponding apertures through the slide casing; F' F' F' are faces between the apertures E', corresponding to the faces F of the expansion slide; M is a steam slide of ordinary construction.

It is evident, that when the apertures E are wholly or partially over the apertures E', the steam will get access to the steam slide M,—but when the faces F F F of the expansion slide cover the apertures E' E' E', the steam will be cut off.

C is the *axis* of the crank-shaft on which the expansive eccentric wheel is supposed to be placed; $C\,g$ is the medium direction of the expansion eccentric rod, on $C\,g$ take the distance $C\,a$ *equal* to the steam aperture E through the slide. Also on $g\,C$ produced take $C\,b$ equal to $C\,a$, and through the points (a), (C), (b), draw the lines $(x\;a\;x')$ $(y\;C\;y')$, $(z\;b\;z')$, perpendicular to $(C\,g)$. If now the slide F be driven by an eccentric wheel, having its centre at (a), and the connexion with the slide be completed, as shewn by the drawing Fig. 1, ($h\;g$ and $h\;i$ being levers supposed in this case to be of equal length); $C\,a$ will be the radius of the circle described by the centre of the eccentric wheel, therefore the throw of the eccentric will be twice $C\,a$, equal to twice the aperture E, and the aperture E of the slide will *just pass over*, but *not* pass beyond, the corresponding aperture E', consequently steam will be admitted throughout the whole revolution; if, however, on the line $(a\;x)$, we take any point (p), and bring the centre of the eccentric wheel up to that point, then $C\,p$ will be the radius of the circle that will be described by the centre of the eccentric wheel, which circle will pass beyond the limits of the lines $(x\;a\;x')$ and $(z\;b\;z')$ cutting those lines at the points $s\;s'\;p'\;p$, and it is evident, that whilst the centre (p) of the eccentric wheel is in the act of passing from p to s, and from s' to p', *between* the lines $(x\;a\;x')$ and $(z\;b\;z')$, the aperture E of the slide will be passing and repassing the port E', and steam will be *admitted;* but when the centre of the eccentric wheel is describing the spaces $s\;s'$ and $p'\;p$, beyond the limits of $(z\;b\;z')$ and $(x\;a\;x')$, the *faces* F of the slide will be opposite the apertures E', and the steam will be *cut off.* It will therefore be observed, that the angles $p\;C\;s$, $s'\;C\;p'$, represent the portions of the revolution during which the steam *passes* the expansion-slide, and the angles $s\;C\;s'$ and $p'\;C\;p$ represent the portions of the revolution during which the faces F of the slide will cover the ports E', and consequently for these periods the steam will be *cut off;* and it is apparent, that the farther the point (p) (on the line $a\;x$) is distant from the point (a), the smaller will be the angles $p\;C\;s$ and $s'\;C\,p'$, in comparison with the angle $s\;C\;s'$ and $p'\;C$ p; that is, the smaller will be the period during which the steam is admitted, in comparison with the period during which the steam is cut off.

If, therefore, we so construct an eccentric wheel, that *its centre may be made to traverse at pleasure on the line* $(a\;x)$, we shall have the means of varying the degree of expansion at pleasure, as may be required.

Fig. 1.



PRACTICAL CONSTRUCTION.

Figs. 2 and 3 show one of the numerous methods of construction whereby an eccentric wheel may have the required property above referred to; viz., its centre (*a*) being made to traverse at pleasure on the *given* line (*a p*), the line (*a p*) *not* passing through (C), the axis of the shaft, but passing at *a given distance* (C *a*) therefrom.

K is a skeleton eccentric wheel, having its centre at (*a*).

L L L L, the void space of the skeleton eccentric wheel, having its opposite sides L L, L L parallel to each other.

M, a block fitted upon the shaft, the opposite sides L M and L M being parallel to each other and perpendicular to the line (C *g*), upon which block the skeleton eccentric wheel is made to slide or traverse the required distance M L, equal to (*a p*), or any part thereof at pleasure.

O, a screw fixed to the rim of the eccentric wheel, and called the leading screw, its axis being parallel to L L.

R, a nut fitted to the block M, working upon the screw O, and made to turn like a swivel by means of the arms projecting from it forming a ratchet wheel, whereby the nut R may be turned by hand when the engine is not in motion, or by one or the other of the moveable finger-pieces, Z Z, when the engine is in action. Or, instead of the nut R being furnished with a ratchet wheel, it may be fitted with a worm wheel, and be operated upon by a tangent screw.

It is apparent, that by this construction the centre (*a*) of the eccentric wheel K may be made to traverse at pleasure upon the line (*a p*), even whilst the engine is in motion, whereby the expansion slide will be operated upon as before described, with reference to fig 1.

Fig. 2.

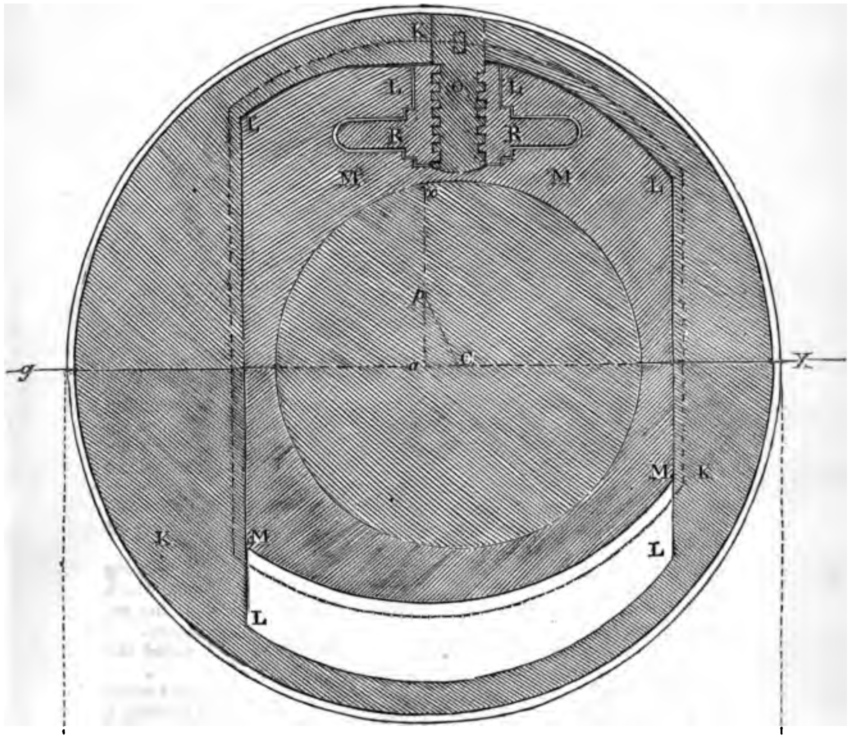


Fig. 3.

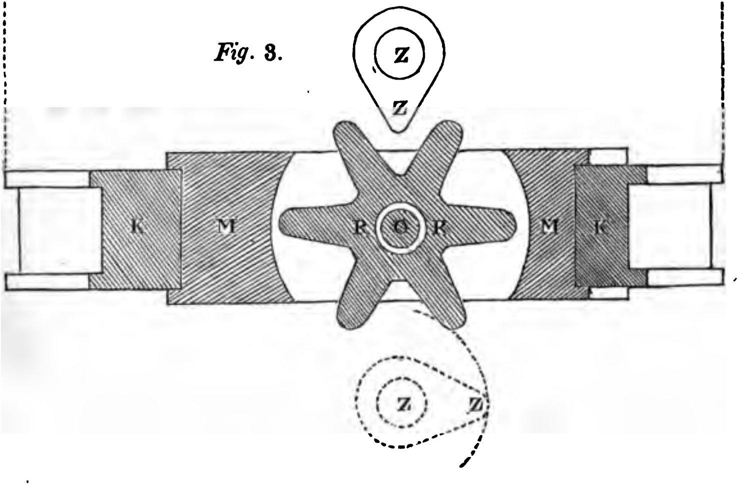
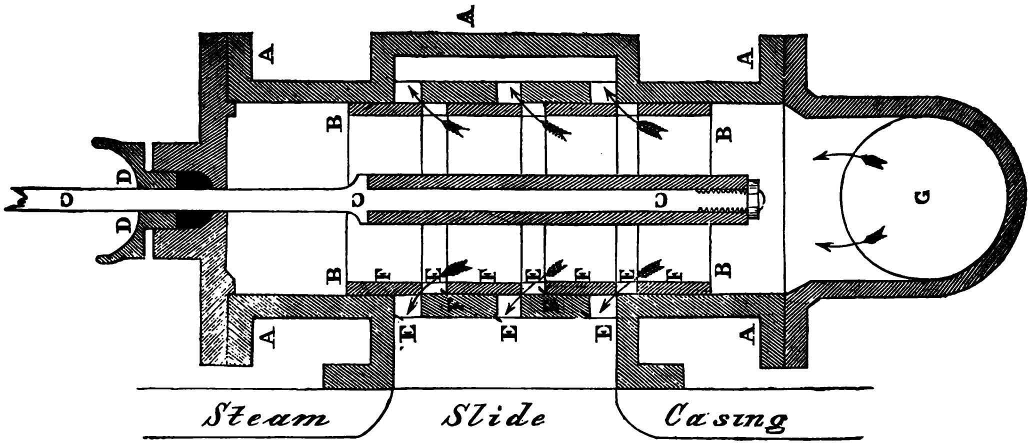


Fig. 4.



The expansion-slide may be either flat, as in fig. 1, with one, two, or more apertures, E, or it may be cylindrical, as in fig. 4; in constructing the expansion-slide, care must be taken that the width of the respective faces, F, between the apertures of the slide, may give a sufficient range for the *extreme travel* of the slide when working the steam expansively in the *greatest* required degree; practically it will be found that if the travel (*a p*) of the eccentric wheel upon the shaft be made equal to three times the distance (C *a*), and consequently that if the width of the faces F and F′ be made three times the width of the apertures E and E′, the steam may then be cut off at any portion of the stroke, not less than ONE-TENTH of the stroke, which limit of expansion embraces all the requirements of marine engine practice.